Forest Report 2025

Development, Condition and Use of Swiss Forests

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Forest Report 2025

Development, Condition and Use of Swiss Forests

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Abstracts

The Forest Report 2025 is the third publication of its kind, with previous versions appearing in 2005 and 2015. It is aimed at experts and anyone interested in forest and wood-related issues. The report provides an overview of the condition and development of Swiss forests over the past ten years and assesses the outlook for all relevant areas against the backdrop of advancing climate change. With a structure modelled on Forest Europe reports, the Forest Report sets out internationally comparable results and serves as a benchmark publication. It uses a broad range of data from long-term surveys to answer important questions for society, economic players and policymakers.

Keywords:
forest, wood,
forest ecosystem services,
climate change,
condition and development,
long-term surveys,
Forest Europe

Der Waldbericht erscheint 2025 zum dritten Mal nach 2005 und 2015. Er richtet sich an Fachleute und an eine am Thema Wald und Holz interessierte Leserschaft. Der Waldbericht ist eine Gesamtschau über Zustand und Entwicklungen des Schweizer Waldes in den letzten zehn Jahren und gibt einen Ausblick für alle Themenbereiche im Hinblick auf den fortschreitenden Klimawandel. Mit seiner an den Berichten von Forest Europe orientierten Struktur liefert der Waldbericht international vergleichbare Ergebnisse und dient als Referenzpublikation. Er beantwortet anhand einer breiten Datenbasis aus Langzeiterhebungen wichtige Fragen für Gesellschaft, Wirtschaft und Politik.

Stichwörter:
Wald, Holz,
Waldleistungen,
Klimawandel,
Zustand und Entwicklung,
Langzeiterhebungen,
Forest Europe

Après 2005 et 2015, le Rapport forestier paraît pour la troisième fois, en 2025. S'adressant aux spécialistes et aux lecteurs intéressés par le thème de la forêt et du bois, il offre un aperçu général de l'état et de l'évolution de la forêt suisse au cours des dix dernières années, et propose pour chaque chapitre thématique un regard vers l'avenir tenant compte des changements climatiques. Structuré de façon similaire aux rapports de Forest Europe, il fournit des informations reproductibles au niveau international et fait figure de publication de référence. Le Rapport forestier répond à des questions importantes pour la société, l'économie et la politique en se fondant sur une vaste base de données issues d'enquêtes à long terme.

Mots-clés :
forêt, bois,
prestations forestières,
changements climatiques,
état et évolution,
enquêtes à long terme,
Forest Europe

Nel 2025 il Rapporto forestale giunge alla sua terza edizione dopo quelle del 2005 e 2015. Destinato ad esperti e lettori interessati al tema del bosco e del legno, il rapporto fornisce uno spaccato generale su stato ed evoluzione del bosco svizzero negli ultimi dieci anni e traccia una prospettiva per tutte le aree tematiche tenendo conto del cambiamento climatico in corso. Essendo strutturato come quelli di Forest Europe, il rapporto mette a disposizione risultati comparabili a livello internazionale e serve come pubblicazione di riferimento. Mediante una vasta base di dati provenienti da rilevamenti di lungo periodo, risponde a interrogativi importanti per la società, l'economia e la politica.

Parole chiave:
bosco, legno,
prestazioni del bosco,
cambiamento climatico,
stato ed evoluzione,
monitoraggio di lungo periodo,
Forest Europe

Foreword

What could be more relaxing than a walk in the local forest – in spring, when the trees and shrubs are a shiny, fresh green, or in autumn, when the forest is at its most colourful again? But this is far from the only public benefit that forests provide. They are eminently versatile. As protective forest, they safeguard against natural hazards such as rockfall, avalanches and debris flows. As habitat, they are home to countless animal and plant species and play a vital role in biodiversity conservation.

The ecosystem services provided by forests are becoming increasingly important, especially in view of climate change. We can feel this at first hand when we step out of an overheated neighbourhood into the cool forest on a summer's day in search of rest and relaxation. Forests help to mitigate climate change by supplying wood, a renewable resource. They also absorb CO_2 from the air, while timber acts as a long-term carbon store. As a source of raw materials, forests are also integral to the economy. The importance of these forest ecosystem services and the many others highlighted in this report is growing all the time.

This Forest Report provides an overview of all aspects of Swiss forests, their condition, development and prospects. Some 90 experts have collated information from a variety of long-term monitoring programmes and skilfully interpreted it in six thematic chapters in order to answer the relevant questions. The essence of the research findings is presented in the Synthesis section, while the Implications section sets out the political action needed to ensure that forests can adapt to changed environmental conditions and continue to provide their ecosystem services in the future.

The report, which has established itself as a benchmark publication, has a sound scientific basis and applies the criteria of Forest Europe. It is aimed at a specialist audience as well as interested members of the public, economic players and policymakers.

How are Swiss forests faring? There are no simple answers to this question. However, one thing is certain: climate change is making its presence felt in forests as elsewhere. The impacts extend beyond direct forest stakeholders, requiring the support and cooperation of society as a whole. It is therefore important that society is well informed of the issues.

We hope that this report, with its comprehensive appraisal of the condition, development and future of Swiss forests, will offer a basis for informed discussions and decision-making.

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Forests in Transition – A synthesis

Andreas Rigling, Michael Husistein, Marco Ferretti, Michael Reinhard

The past decade has been one of the most turbulent ever, with far-reaching consequences for Swiss forests, their management and the entire forest and wood value chain. The current condition of forests may therefore be assessed as 'weakened' or even 'critical', depending on the perspective and region. Vital and healthy forest is of great value to Switzerland as a whole, providing a wide range of services to society: supplying wood as a raw material, protecting against avalanches, landslides and other natural hazards, safeguarding against erosion, purifying drinking water, sequestering carbon from the air, serving as a recreational space for the public, and, last but not least, playing a vital role as a haven for biodiversity. The importance of many forest ecosystem services and of biodiversity is increasing all the time as environmental changes progress and the demands of the various stakeholders grow.

Over the past decade, global megatrends have directly or indirectly influenced the development of Swiss forests.

- **Climate change** (IPCC 2022): Ever more frequent disturbances and extreme events such as storms, heatwaves and droughts are causing increasingly visible damage to forests and, in some areas, extensive tree dieback. This can impair forest ecosystem services that are particularly important in the face of climate change, e.g. protection against natural hazards, wood production and carbon sequestration as a contribution to climate change mitigation.
- **Global biodiversity loss** (IPBES 2019a): Forty per cent of all animal and plant species in Switzerland live in or depend on forests. As a close-to-nature habitat, they therefore make a major contribution to protecting and conserving biodiversity. However, there are also threatened species and habitats requiring special protection within forests and especially at the interface between forests and open land.
- **Globalisation of trade:** International goods and passenger transport can introduce especially dangerous harmful organisms, including plants, fungi and insects (Bonnamour et al. 2021). These can displace native forest species and thus damage the entire forest ecosystem. Import checks, monitoring and targeted control are therefore essential, and failing this the controlled integration of non-native harmful organisms as part of forest management.
- **Global raw material shortages** (IRP 2019): Demand for wood, a renewable raw material, is rising sharply. The use of wood is recommended from an economic and environmental perspective provided it is based on sustainable production and takes place in regional value chains.
- **Urbanisation** (United Nations 2018): Forests are increasingly being used as recreational areas owing to population growth and changes in leisure behaviour and are becoming more important for public health. This places additional pressure on these habitats and poses major challenges for forest management.

The aim of this synthesis is to contextualise the findings of the Forest Report 2025 within these global processes.

Forests are undergoing fundamental change

Swiss forests cover around 1.3 million hectares or just under a third of the country's total area. For the first time in decades, the forest area has expanded only slightly over the past ten years. On the densely populated Plateau and in the valleys, forests are even coming under increasing pressure due to competing demands for space. Here in particular, preserving the forest area is an ongoing challenge.

A similar change in trend is apparent in the growing stock of living trees: the sharp rise around the turn of the millennium has slowed, with stocks remaining largely unchanged since 2015. In the Alps and on the southern side of the Alps it is still increasing, whereas in the Jura and on the Plateau the growing stock has declined, mainly because drought, insect infestation and tree diseases have increased tree mortality, but also because more wood is being used as a raw material in these regions.

Spruce remains the most widespread tree species in Swiss forests, accounting for 42% of the total growing stock, followed by beech on 18%. Nationwide, the proportion of conifers has remained constant over the past decade, at two thirds. However, distinct changes in the tree species composition are becoming apparent at regional level, with the proportion of spruce on the Plateau and in the Jura falling by 15% and 10% respectively. Beech has also lost a lot of ground in the Jura, while in the Alps and on the southern side of the Alps the proportion of beech has climbed by 8% and 20% respectively. Ash stocks have decreased, mainly due to ash dieback, while sycamore, fir and larch have increased notably. These significant shifts in tree species will have a lasting impact on forest dynamics.

In addition to tree species composition, the forest structure, the age distribution of trees and the extent and quality of regeneration also influence future forest development. Richly structured forests featuring trees of different heights and a wide range of age classes are more resilient to environmental changes: they suffer less damage and recover more quickly after disturbances and extreme events, which are becoming increasingly frequent as a result of climate change. Although an impressive 64% of Switzerland's forest area is multi-layered and tiered, the regeneration of future-adapted tree species is inadequate in many places, especially where advance regeneration is sparse. Advance regeneration refers to young trees that have been able to establish themselves under the canopy of the main stand. Forests with sufficient advance regeneration are more resilient because post-disturbance reforestation takes place faster if young trees are already in place.

Forest's ability to sequester carbon from the air by means of photosynthesis is one of its most important services in the face of climate change. Swiss forests store an average of 269 tonnes of carbon per hectare, more than half of it in the soil. Forest soils in Switzerland are particularly large sinks, storing around 50% more carbon than those in other Central European countries. There are several reasons for this: the advanced age of the forest, the cool and damp climate, which favours the accumulation of carbon in the soil, and the close-to-nature forest management, which causes less soil damage.

The continuous expansion of the forest area and increase in growing stock over the past 40 years meant that the forest mostly functioned as a carbon sink during this time. However, given the change in the growth trend highlighted in this report as well as disturbances and extreme events due to climate change, there is a risk that forests will increasingly become a carbon source in some places and that the overall sink effect will decrease. To counteract this and bolster forest's three climate services (carbon sequestration in forests, carbon storage in wood products, substitution of wood for more climate-damaging raw materials and fuels), there is a need to strengthen forest resilience by means of silvicultural measures and promote the use of wood as a material, e.g. in furniture and buildings.

Climate change is placing forests under stress

The rapid advance of climate change has significantly increased the threat to forests. Over the past decade, many disturbances and extreme events damaged forests at a local and regional level: the spring drought in 2015, the late frost in 2017, storms Eleanor (Burglind) and Vaia (Adrian) in 2018, the hail events in central Switzerland in June 2021, and the heatwaves and summer droughts in 2018, 2019, 2022 and 2023, which were often followed by a severe bark beetle infestation. These events occurring in quick succession had mutually reinforcing effects, and recovery periods, in the form of cooler years with sufficient precipitation and low pressure from harmful organisms, were lacking. Such periods allow trees to adapt their metabolism and forests to replenish their water reserves. Other stress factors such as excessive nitrogen pollution and ground-level ozone exacerbated the situation. While this pollution has been reduced in recent years, it still exceeds the critical loads in many places and so can inhibit forest's growth and drought resistance (Etzold et al. 2021), making the forest ecosystem more susceptible to infestation by harmful organisms.

Another key factor is non-native harmful organisms that enter Switzerland via increasingly globalised trade. A current example is ash dieback. The disease is caused by an East Asian fungus that probably arrived in Europe with plant material in the 1990s. Ash dieback was first detected in Switzerland in 2008 and has since spread epidemically. It mainly kills young ash trees, but also affects old stands (Dubach et al. 2023). Consequently, the once staple ash threatens to disappear from regular forest management.

However, 2–5% of ash trees are resistant, and it is vital that these are protected and promoted so that the resistance can be passed on to their offspring. This could preserve the ash, and indeed its characteristics as a fast-growing tree with relatively high drought resistance and excellent wood quality mean that it could be one of the tree species of the future, with a key role to play in adapting forests to climate change.

Compared with the large-scale monocultures in neighbouring countries, Swiss forests, which are mostly managed in a close-to-nature way, have a more diverse structure and are therefore more resistant to the effects of climate change. However, given the increase in forest damage over the past decade, including in Switzerland, forest management must be proactively realigned towards adaptive, close-to-nature forest management (Larsen et al. 2022). One possible measure is using disturbed areas to promote rare tree species or to introduce small groups of additional tree species that will thrive in the future climate, thereby enabling the development of mixed forests with a high diversity of tree species, which are generally more resilient.

Comprehensively promoting forest biodiversity

Alongside climate change, the progressive loss of species is one of the greatest global threats of our time, as biodiversity is the basis of many ecosystem services that are essential for human life. Around 40% of the approximately 56,000 plant, fungi and animal species recorded in Switzerland live in or depend on forests, making this one of the most species-rich habitats in the country. Encouragingly, there has been a slight improvement in forest biodiversity. The populations of many woodland bird species have grown over the past decade, for example, and the diversity of gastropod (snail and slug), moss and tree species has also expanded.

The increase in deadwood – an essential habitat for many specialist species – is having a positive impact on forest biodiversity. This increase is a consequence of greater tree mortality following disturbance events as well as of forest management practices that recognise the value of deadwood for biodiversity. Nationwide, the volume of deadwood in forests now stands at 32 cubic metres per hectare, although there are still deficiencies in some regions. In addition, rising demand for energy wood is jeopardising the positive trend in deadwood as increasing amounts are being burnt.

Progress has also been made on nature reserves and special forest reserves. By 2022, 7% of the total forest area had been designated as protected area, primarily in the Alpine regions. The Federal Council's goal of protecting 10% by 2030 is therefore within reach.

These positive developments should not obscure the problems that still exist. Among vascular plants, for example, 13% of forest species are considered endangered, as are nearly half of the wood-dwelling beetle species that depend on deadwood. There also remain major issues with habitat quality in some regions. For instance, 70% of forests on the Plateau still have an unnaturally high proportion of spruce. Furthermore, 41% of forest communities and their habitats are considered endangered, in particular alluvial forest areas, open forests, and old and large-diameter trees, which provide a wide variety of microhabitats for specialist species.

Alongside close-to-nature forest management, another key factor in conserving forest biodiversity are the interfaces between forest and agriculture, notably forest edges and the linking of forest areas by hedges, groups of trees and individual trees in the landscape. However, the data in this Forest Report show that, at altitudes below 600m a.s.l., around 30% of open areas have been cleared and lack such structural elements, which would normally act as a bridge to other habitats for many species. They are a key component of the efficient ecological connectivity envisaged by the Confederation, which aims to link areas with a high number of species and habitats via protection and connectivity zones. Achieving these goals requires integrated forest and landscape management (Krumm et al. 2020) and close cooperation between representatives of forestry, agriculture and nature conservation.

In Switzerland, 90% of forests are naturally regenerated, i.e. the young trees are the result of natural seeding. Natural regeneration helps ensure a high genetic diversity of trees, which favours forest's adaptation to climate change. However, excessive game populations in some areas impair natural regeneration and the natural adaptive potential of the forest, as the animals browse on the saplings of ecologically valuable tree species.

Equally important for climate-adapted forests is a sufficient diversity of tree species. This applies from both an ecological and an economic point of view. Indeed, mixed forests with a high diversity of tree species are more resilient to the effects of climate change, and they also mean that the economic risk of losses following disturbances such as windthrow or bark beetle infestation is spread across multiple tree species. In order to maintain the various forest ecosystem services in the face of climate change, wood supply in particular, native and non-native tree species that are currently rare but are better suited to future conditions could become more important in Swiss forests. The ecological and economic effects of such admixtures are being researched in depth but are as yet difficult to estimate.

Limited room for manoeuvre on protective forest

Nationwide, 44% of the forest area is designated as protective forest, meaning that it protects people and infrastructure from natural hazards such as avalanches, rockfall, landslides and debris flows. Protective forests are a cost-effective prevention measure and a key component of integrated risk management. Without them, life in the mountains would be scarcely conceivable. There are also protective forests at lower altitudes and on the Plateau. In addition, healthy forest soil filters seepage water and thus improves the quality of drinking water.

Protective forests are becoming increasingly important as the population grows, and with it the infrastructure that needs to be protected, and as climate change makes natural hazards such as rockfall more common. However, climate change effects are also damaging protective forest. After the hot, dry summers of 2018 and 2022, subalpine mountain forests suffered massively from drought stress, and at higher altitudes bark beetle infestations caused extensive damage to coniferous forests (Dubach et al. 2023). Yet only a forest in good condition can guarantee long-term protection. Firstly, it must be densely enough stocked with healthy trees, and secondly, sufficient forest regeneration is essential so that young trees can take over the protective function seamlessly when old trees die or are harvested. Both these things require a minimum level of protective forest tending, as laid down in the Forest Act, with implementation specified by the Confederation and cantons (FOEN 2024). Tending protective forests to ensure their long-term protective effect is becoming an ever-greater challenge because of climate change.

In the past decade, 17% of protective forest area nationwide was tended, but overall, protective forests have become denser in many places during this period. While this increases the protective effect in the short term, the densification can have negative long-term consequences as the forests become darker and more homogeneous. In the Alpine regions, around 40% of protective forests are already single-layered. Low light availability in the increasingly dense stands and high levels of ungulate browsing of young trees in some areas prevent sufficient regeneration under the canopy of the main stand. The proportion of protective forest with little secondary growth has increased in the past decade and now stands at 30%. Young fir, maple and oak trees – species regarded as fit for the future and therefore to be promoted – are particularly affected by ungulate browsing. This may jeopardise the protective effect in some areas, so regionally coordinated measures need to be taken quickly. Silvicultural interventions and the regulation of game populations must be carefully coordinated with hunting and nature conservation representatives.

In the light of climate change, both the protective forests themselves and the way in which they are managed need to be adapted. This is particularly challenging in protective forests because they are often located at higher altitudes where the choice of tree species is limited. Protective forests must be managed in such a way as to ensure an adequate protective effect in the long term. Consequently, there is limited scope for interventions and experiments, for example involving non-local or non-native tree species. Rather, the decisive factor is sufficient advance regeneration. In addition, deadwood left in situ, with its braking effect, increases residual protection against avalanches, rockfall and landslides over decades, as well as promoting forest regeneration and structurally richer stands (Bebi et al. 2023).

Securing wood supply and processing

For the first time in decades, the wood volume increment has fallen over the past ten years in some regions. The gross increment, factoring in the growth of living trees and the volume of losses (standing and lying dead trees and trees removed from the forest), dropped by 2.2% compared with the previous decade. Tree mortality has increased massively and now stands at 25% of the gross increment. The net increment, which only includes the change in living trees, fell by as much as 13%. Regular harvesting has decreased slightly across the country as a whole.

One indicator of the sustainable use of wood as a resource is the ratio of harvesting to net increment. Sustainable use means that, over the long term, the amount of wood felled equals the amount that grows. This is the case if average harvesting over several decades totals 100% of the net increment. Due to the current decline in increment, the ratio of harvesting to net increment has risen slightly nationwide in the past decade, to 89%. In the Jura and on the Plateau, harvesting now even significantly exceeds net increment, leading to the depletion of growing stocks that have accumulated over decades due to underuse. Less wood is harvested in the Alps and on the southern side of the Alps, meaning that growing stocks are also high in these areas. In other words, the amount of potentially harvestable wood still varies from region to region. Potential lies in stands that could be used more intensively up to the net increment, in still high growing stocks, in wood from urgent climate change adaptation measures, and where wood from previous forest management has been left lying.

Demand for wood has risen sharply, with wood end use up by over 15% compared with the previous decade. The use of wood as part of the circular economy is desirable and can make an important contribution to meeting Switzerland's net-zero target by 2050. However, supplying the timber market will be a challenge for the forestry sector going forward.

For a long time, over half of the wood harvested in forests was used as material, i.e. in furniture or buildings. In the past decade, however, material use has fallen from 52% to 41%, while energy use (burning wood to generate heat or electricity) has increased to around 56%. Total energy wood consumption in 2021 was around 5.8 million cubic metres, almost half of which was harvested in forests. The rest comprised wood from woodland fragments, residuals from wood processing and waste wood previously used for other purposes. Moreover, to meet the rising demand for renewable energy, Switzerland imported a record amount of fuelwood products in 2022 – around 346,000 tonnes. Wood energy now accounts for nearly 6% of total final energy consumption. Wood is Switzerland's second most important renewable energy source after hydropower.

Today, up to 70% of the hardwood harvested in forests is already used for energy production, and that proportion could increase further as demand for energy wood grows. These quantities can therefore no longer be used as construction timber. The direct burning of forest-harvested wood that could actually be used for material purposes is undesirable on climate and resource efficiency grounds and because of its lower value added when used as material. While using wood as a renewable energy resource does have a substitution effect if fewer fossil fuels are burnt as a result, it also means that no additional carbon is sequestered from the atmosphere. Conversely, if forest wood is used as a material and in construction, the carbon remains stored for longer. That is why Switzerland aims for cascade use (FOEN 2021b). This posits that forest wood should first be used as a material and only burnt at the end of its life cycle, e.g. as waste wood from buildings or furniture.

The wood industry mainly processes softwood. If this becomes scarcer because of a collapse in spruce wood production at lower altitudes due to the effects of climate change, the sector will have to adapt. It has three options here. It could switch to hardwood, although this would require a radical change to the wood processing chain. Another strategy could be to import more softwood; however, this runs counter to the goal of strengthening the value chain, which is desirable for environmental and climate policy reasons as well as economically.

The third option would be more intensive harvesting of softwood from Swiss forests, but this strategy too has its limitations. At present, increased harvesting is only conceivable in the Alps and on the southern side of the Alps. This is where the largest softwood reserves are located and, in contrast to the Plateau and Jura, the amount of wood harvested is still well below the increment. Because of the rough terrain and poor accessibility, the costs of harvesting and removal are much higher in the Alps and on the southern side of the Alps than in the other production regions. The key questions are therefore whether sufficient wood can be produced at all with adaptive close-to-nature forest management in the face of climate change, and whether domestic wood production is economically viable and ecologically justifiable at the same time. Do alternative, non-native tree species such as Douglas fir need to be added in order to continue producing softwood on the Plateau, in the Jura and in the Pre-Alps? Should systems with short rotation periods and small-scale plantation forestry be considered in addition to established close-to-nature management? And if so, at which sites, to what extent and with which tree species? What form should compensation measures to promote biodiversity and other forest ecosystem services take – measures that would be constrained by the operation of these more intensive harvesting systems? These questions remain largely unanswered. Assuming that the demand for wood will continue to rise in Switzerland and worldwide, it will still be worth including economically viable tree species in mixed forests in the future. Another factor to consider is that supplying wood as a resource domestically would also help to secure domestic value added from the processing of the harvested wood through to the resulting wood products. Moreover, fewer emissions would be generated by transport and consumers could be sure that the wood came from sustainable production.

Challenges for forestry

The drastic changes in forests also pose major challenges for forest owners and the enterprises that manage forest. Around 71% of Switzerland's total forest area is publicly owned, with each owner holding an average of 265 hectares. The remaining 29% belongs to private individuals, who own an average area of just 1.5 hectares. These small-scale ownership structures result in a variety of management methods, but make it difficult to coordinate the measures that are increasingly necessary in the face of climate change.

Around half of forest enterprises currently operate at a profit or break even. The average annual financial loss of forest enterprises as a whole fell from CHF 58 million in 2012 to CHF 6.5 million in 2021 on the back of a significant rise in timber prices since 2020. Their biggest source of income continued to be timber revenue, followed by publicly subsidised protective forest management.

Forest owners and enterprises are not remunerated for many of the services that forests provide to the public or specific stakeholders. For example, population growth, increasing urban density and the trend towards a leisure society mean that forests are increasingly being used as recreational spaces. This can entail massive additional costs. On the other hand, remuneration for leisure activities and the sale of climate certificates could generate additional sources of income. Non-wood forest products such as mushrooms, forest honey, Christmas trees, chestnuts and game meat (e.g. venison) are becoming increasingly popular. As a result, the planning of forest management measures is proving ever more complex and is also fraught with uncertainty because of rapid climate-related changes. State-of-the-art remote sensing technologies (lidar, satellite data) for recording the condition of forests, decision-making aids and simulation models optimised with artificial intelligence, new methods for tracking the supply chain and advances in digitalisation can help to integrate flexible and reliable concepts such as new certification approaches into forest planning.

Conclusion: Upheaval in Swiss forests

The Forest Report shows that forests, forest management, and the forest and wood value chain are in a state of upheaval. Changing environmental, economic and social conditions are posing major challenges. This Conclusion section sets out the technical implications from the findings presented in the Forest Report for the forest and wood sector. The issues that arise from this can only be addressed through dialogue among all stakeholders. Combined with a growing interest in forests in broad sections of the population, this presents an opportunity to rethink and adapt existing viewpoints, concepts and processes. In this way, the forestry and wood industries could become a key component of the circular economy and thus support the objectives of the Confederation's environmental and climate policy. However, the associated challenges can only be overcome if we as a society succeed in creating the conditions to enable forests to adapt to climate change.

Maintaining **flexibility for the future** will require a sufficient diversity of tree species. Natural regeneration and targeted supplementary planting can encourage future-proof tree species that enhance the overall adaptability of the forest. Native species should take top priority here, followed by species native to drier and warmer regions such as beeches from southern Italy. Non-invasive, non-native tree species should only be considered as a third-level priority. Any shifts in and additions to the tree species composition should be tested experimentally and the effects on required forest ecosystem services and on biodiversity assessed using simulation models.

The further development of close-to-nature forest management will help forests adapt to climate change and promote biodiversity, tree species diversity and structural diversity. Such adaptive forest management integrates disturbances into planning from the outset and establishes targeted measures to promote species diversity in forest management, e.g. leaving deadwood and habitat trees in the forest or designating forest reserves. Whether, and in what forms of management, non-native tree species could be added needs to be clarified. Securing the future supply of wood for material use, including softwood, is a key factor here. In addition to adaptive, close-to-nature forest management, **integrated forest management** that promotes multiple forest ecosystem services simultaneously should be rolled out more widely. Forests should be seen as part of the landscape, one that strategically connects different habitats across the country.

The **forest and wood value chain**, from raw materials production and processing through to product use, will need to adapt to the altered conditions. Climate change will lead to shifts in the proportions of tree species in some areas. More drought-resistant broadleaved species may benefit in certain regions, with a corresponding decline in the proportion of conifers. This could pose a challenge for the supply chain, which currently relies heavily on softwood, especially for construction timber. New types and assortments of wood will require new technical processes and wood products, changes in application and new industry networks that also use these products.

The upcoming changes will result in **conflicting interests in forest management**. There is a conflicting interest, for example, between the increasing demand for energy wood on the one hand and the need for more deadwood, old-growth patches and habitat trees in forests to protect habitats and species on the other. If forests are to provide a range of services in line with the principle of forest multi-functionality, areas of conflict must be recognised at an early stage and integrated into forest planning. This will allow for solutions geared towards synergy rather than opposition.

Conflicts of interest between **forestry, game, agriculture and nature conservation**, such as ungulate browsing, which is much too high in some areas and negatively impacts forest functions, must be resolved holistically and at the appropriate level. For example, although large carnivores such as wolves are detrimental to livestock, they also help to regulate game populations in forests and so reduce excessive ungulate browsing (Kupferschmid and Bollmann 2016). The risks and benefits of such regulation should be weighed up jointly and constructively by stakeholders locally.

Long-term and regular environmental monitoring is essential in order to overcome these challenges. Such monitoring highlights forest condition and development, allowing changes and their causes to be identified early on (Ferretti et al. 2024). On this basis, representatives from all stakeholder groups must step up dialogue in order to jointly develop sustainable paths for the future. In some areas, the changes will require systemic adjustments that must be taken on board quickly by professionals, researchers and administrative bodies and, above all, by training providers. This will enable Swiss forests to go on supplying the services that society needs in the future.

Implications

Michael Husistein, Alexandra Strauss, Michael Reinhard

This section is a summary aimed at political, economic and civil-society decision makers. The implications drawn are based on the findings of the specialised chapters as well as the Synthesis section and associated conclusion of the Forest Report 2025.

Policy framework
In its Forest Policy 2020, Forest Policy: objectives and measures 2021–2024 and Wood Resource Policy 2030, the Confederation set out the strategic direction for the past ten years, including the amendment to the Forest Act, which came into force on 1 January 2017. This milestone featured additions on adapting forests to climate change, protecting them from harmful organisms and promoting wood processing and use. 2025 will see the publication of the Federal Council's Integral forest and wood strategy 2050, which brings these policies together.

Changing environmental conditions
Climate change is set to increasingly impact forest ecosystem conditions. Extreme events such as drought, storms and forest fires, combined with harmful organisms and high nitrogen deposition, are already visibly affecting forests today, with implications for protective forests and the habitats of countless animal and plant species. Demand for wood, a renewable but limited resource, is growing. Climate change means that more hardwood will be available on the timber market in the future. Leisure and recreational use and the associated demands on forests are also increasing. The key question is: can the forest ecosystem be sufficiently supported to enable it to provide its important services to society in rapidly changing conditions? The Forest Report shows that the diverse functions of forests will become more important as climate change progresses. Synergies and any trade-offs must be identified and analysed in depth for potential interactions, with this then used as a basis for developing harmonised measures at the appropriate levels (national, cantonal and regional).

Conserving the forest ecosystem
In order to conserve forests as a resilient and adaptable ecosystem in the face of global change, the following challenges must be overcome:

- **Forests' adaptability to climate change** must be maintained. Central to this is regeneration, which should be site-appropriate and suited to future climatic conditions. This requires regeneration harvesting and subsequent regular forest tending. Sufficient regeneration must also be ensured by means of hunting (regulation of game populations to reduce ungulate browsing) and silvicultural measures (habitat enhancement). Forest management that promotes diversity of forest structures and tree species as well as genetic diversity of trees supports adaptability and reduces the risks of forest damage following disturbances and extreme events. Depending on the stand and site, shortening the rotation period may also reduce the risk. Stands that are particularly sensitive to climate change should be identified and given special consideration in forest management.
- The **spatial distribution of the forest area** should be preserved. The statutory forest conservation requirement must be upheld. Particularly on the Plateau and in the valleys, great importance must be attached to conserving forest areas and with them the services they provide for society, in the face of increasingly competing demands for space.
- The positive developments in **forest biodiversity** must be maintained, especially given biodiversity loss outside of forests. This requires habitat enhancement in the form of forest reserves, open forests, deadwood and high-quality forest edges. Regional deficiencies must be remedied. To enable species communities to adapt to climate change, it is vital to build and develop connected, high-quality habitats within forests and to link these with neighbouring ecosystems.
- **Forest vitality and health** must be enhanced. Many stress factors are set to occur more frequently and in different combinations in the future. Influenceable factors such as greenhouse gas emissions, excessive nitrogen deposition, the spread of harmful organisms and human-induced forest fires must be reduced. Effective measures are required to prevent or curb these factors and to prepare for possible incident management.

Maintaining forest functions

Only if these challenges are successfully overcome will forests be able to continue fulfilling their multiple functions while being managed sustainably. The following services are particularly significant:

- **Protective forests** protect people and infrastructure from natural hazards. The aim of tending measures in protective forests is to ensure that the required protective effect continues in the long term, even in a changing climate. Key factors here are species-rich, climate-adapted regeneration and diversely structured stands, yet more and more protective forests lack sufficient regeneration and many stands have too little structure. This makes the forests susceptible to disturbances. For protective forests to be able to provide their service in the long term, timely tending measures and measures for climate change adaptation and effective forest and game management tailored to regional conditions are required.
- The move towards a circular economy and bioeconomy is pushing up demand for **wood as a resource**. This makes sustainable and resource-efficient use in accordance with the cascade principle all the more important. This principle states that wood resources should be used for energy only when they can no longer be used as materials. Cascade use makes sense on both ecological and economic grounds, but it requires a closed, autonomous, efficient and innovative value chain that can develop new wood-based products and devise strategies to deal with changing wood resources (e.g. more hardwood). To achieve this, a framework must be created that ensures adequate planning and investment security, and funding for research through to pilot projects must be secured.
- Forest management and wood use **contribute to climate change mitigation** by storing CO_2 in forests (carbon sequestration) and wood products (carbon storage in wood and material substitution for more climate-damaging materials) and by replacing more carbon-intensive energy sources with wood for energy generation (energy substitution). These climate services must be strengthened, taking into account the cascade principle. Those working in the forestry and wood industries should develop targeted projects within the available instruments.
- Forests are becoming **increasingly important for leisure and recreation**, with green spaces being used more and more frequently, especially in and around cities. The provision of these services requires careful coordination of interests. The additional expenses or reduced income resulting from such use must be compensated.

The way ahead

The findings from the Forest Report 2025 are incorporated into the Integrated Forest and Wood Strategy 2050. This strategy proposes measures for all action areas and shows the direction to be taken by the forest and wood sector. Aiming to strike a balance between protection and use, it takes into account sectoral policies such as climate, energy, biodiversity, spatial planning and the circular economy. The strategy is based on the principle of cooperation between the Confederation and cantons and involves all relevant stakeholders in the forest and wood sector. Policymakers are urged to put in place the framework required to create healthy forests adapted to climate change. Key to this are effective coordination and constructive cooperation between policymakers, authorities, business, science and civil society.

Data Basis

Christoph Fischer, Alexandra Strauss

Comprehensive long-term monitoring
The Forest Report is underpinned by an exceptionally broad set of data derived from long-term surveys and a stringent interpretation of these data based on the standardised and recognised indicators of Forest Europe (Forest Europe 2020). Its comprehensively designed data basis, the international comparability of its results and the placing of those results in the context of relevant issues have established the Forest Report as a benchmark publication in the forest and wood sector. It takes into account data available up to July 2023.

Around 90 experts contributed to the Forest Report 2025. It is structured in six specialised chapters corresponding to the sustainable forest management criteria defined by Forest Europe. These chapters are divided into sections based on the Forest Europe indicators, although the report deviates from this structure at times in order to address country-specific aspects of Swiss forests. Chapter 2, for example, includes a section 2.5 entitled 'Impact of climate change on health and vitality'.

Data collected over a long period and interpreted across the entire spectrum of indicators allow an informed assessment to be made of the sustainability of forest management. The surveys on which the Forest Report 2025 is based are presented and described below.

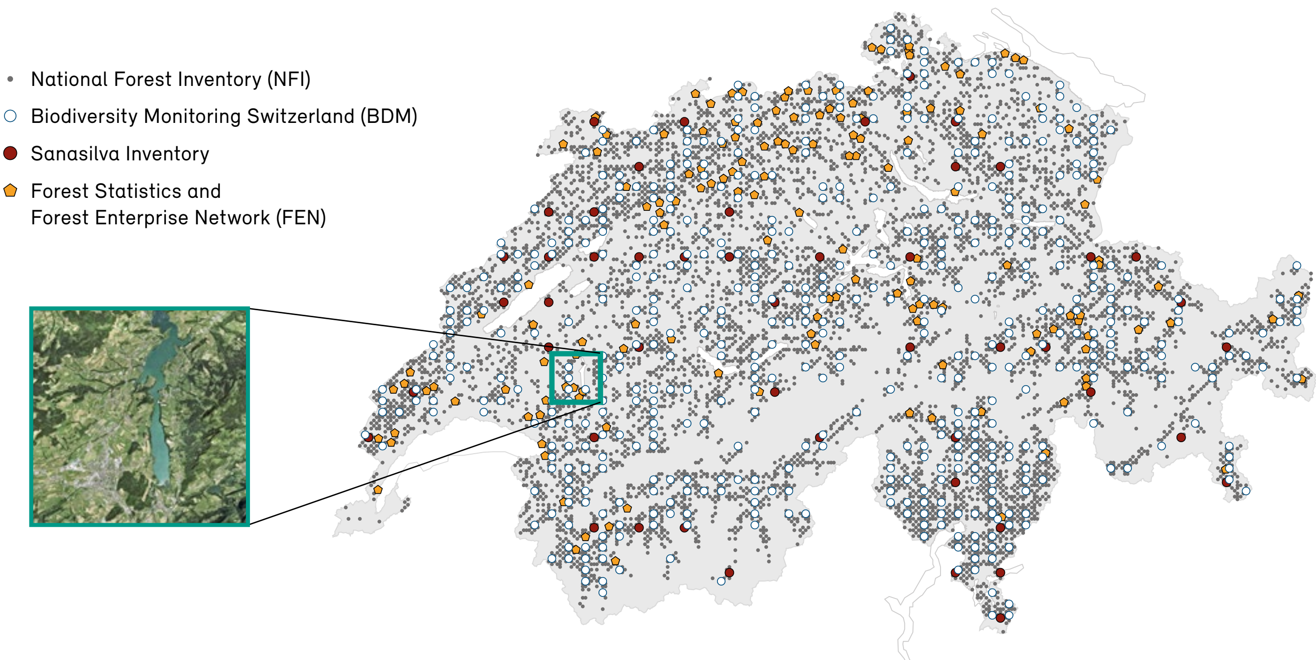
Key

Statistical survey

Survey

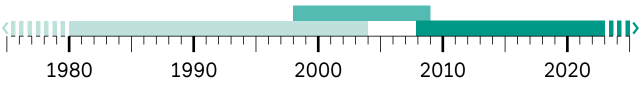
Field observation or measurement

Figure 0.4.1
Nationwide surveys



Remote sensing

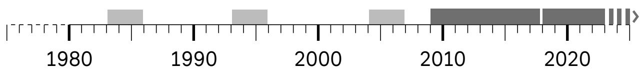
WSL analysis of swisstopo aerial photographs to investigate forest and landscape developments



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

National Forest Inventory (NFI)

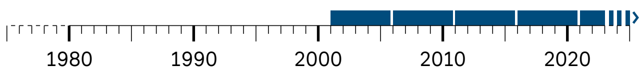
Records the condition of and changes in Swiss forests on around 6,700 sample plots.



- NFI1 1983–85; NFI2 1993–95; NFI3 2004–06
- Continuous data collection since 2009: NFI4 2009–17; NFI5 2018–26

Swiss Biodiversity Monitoring (BDM)

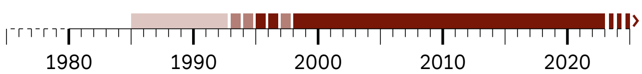
Monitors the development of forest biodiversity based on an NFI subsample.



- Continuous data collection since 2001: 1st survey 2001–05; 2nd survey 2006–10; 3rd survey 2011–15; 4th survey 2016–20; 5th survey 2021–25

Sanasilva Inventory

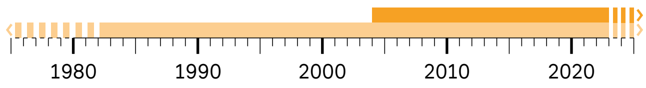
Records the health status of trees (defoliation and mortality) based on an NFI subsample.



- 1985–92: approx. 8,000 trees on 700 plots in a 4×4km grid
- 1993, 1994, 1997: approx. 4,000 trees on 170 plots in an 8×8km grid
- 1995, 1996 and since 1998: approx. 1,100 trees on 49 plots in a 16×16km grid

Forest Statistics and Forest Enterprise Network (FEN)

Comprehensive survey of all forest owners (Forest Statistics) and sample survey of 160 public forest enterprises (FEN).



- Since 1923: annual forest statistics
- Since 2004: Forest Enterprise Network (FEN)

Not shown in Figure 0.4.1:

InfoSpecies

Umbrella organisation for species promotion. Systematically records the distribution and occurrence of animal, plant and fungi species as well as reports from volunteers.

- 1950–59: surveys for the historical breeding bird atlas
- 1967–79: surveys for the Swiss distribution atlas of ferns and flowering plants
- Since 1980: systematic surveys of various groups of organisms

Socio-Cultural Forest Monitoring (WaMos)

Analyses public attitudes towards forests based on representative household surveys.

- 1978: precursor study Hertig
- 1997: WaMos 1
- 2010: WaMos 2
- 2020: WaMos 3

Land Use Statistics (Arealstatistik)

Collects information on land use and land cover on a 100×100m sample grid.

- AREA 1 1979–85; AREA 2 1992–97; AREA 3 2004–09; AREA 4 2013–18; AREA 5 2020–25

Swiss Forest Protection

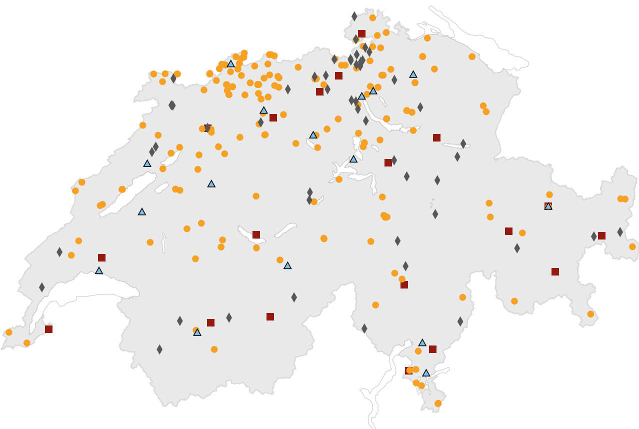
Records stresses in the forest due to frost damage and harmful organisms (insects, fungi, wild ungulates).

- Since 1984

Figure 0.4.2

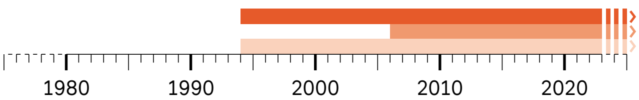
Targeted surveys on selected sites

- Long-Term Forest Ecosystem Research (LWF)
- Intercantonal Forest Observation Programme (WDB)
- Monitoring the effectiveness of natural forest reserves (NFRs)
- National Air Pollution Monitoring Network (NABEL)



Long-Term Forest Ecosystem Research (LWF)

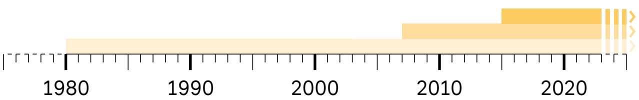
Investigates the effects of air pollution and climate change on forests.



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

Intercantonal Forest Observation Programme (WDB)

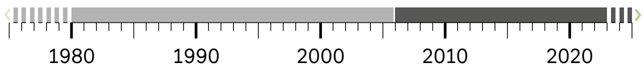
Records and documents forest health and vitality on 188 observation plots.



- Since 1984: in the cantons AG, BE, BL, BS, SO, ZG, ZH
- Since 2007: also in the canton TG
- Since 2015: also in the cantons GR, LU, NW, OW, SZ, UR

Monitoring of Natural Forest Reserves in Switzerland

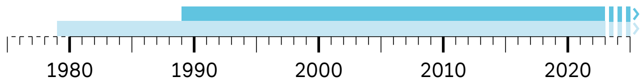
Recording and evaluating the development of forest in reserves since 1948.



- 1948–2005: ETH research at 39 reserves
- Since 2006: WSL, ETH and FOEN research at 49 reserves with modified methods

National Air Pollution Monitoring Network (NABEL)

Measures air pollution at 16 varied locations (city centre, rural areas, high mountains).



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

Other data bases for the Forest Report 2025

- Deforestation statistics: authorised deforestation
- Hunting statistics: development of animal numbers
- National Groundwater Monitoring (NAQUA)
- Swissfire forest fire database
- Species monitoring in natural forest reserves: survey of saproxylic species as indicators of naturalness
- Wood energy statistics: wood-fuelled furnaces/burners
- Company structure statistics: based on OASI office registers
- Landscape Monitoring Switzerland (LABES): around 30 indicators on landscape quality

1 Resources

Forests are an iconic part of the Swiss landscape: Mountain forest on the Sibe Hängste massif (BE), with the Schreckhorn in the background.
Photo: Simon Speich (NFI)

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1 Resources

Christoph Fischer, Michael Husistein

Swiss forests perform a variety of services, including storing carbon and supplying renewable raw materials. The forest area has increased only slightly in the past decade, mainly at high altitudes where Alpine farming has been abandoned. The growing stock nationwide has remained constant at 420 million cubic metres. However, trends have varied from region to region. In the Alps and on the southern side of the Alps, the growing stock has increased, whereas there has been a slight decrease in the Jura and on the Plateau. These developments are due in particular to different intensities of use and to losses caused by climatic changes. The latter has resulted in a high mortality and increased salvage logging, with spruce and beech in climate-sensitive locations hit particularly hard. Structurally diverse forests and species-rich mixed stands can adapt better to climatic changes. They will also result in changes in the quantity and quality of timber supply. Young trees are the forest of the future. In order to maintain resilient forests with sustainable forest regeneration, the diversity of forest structures should be actively promoted. Adapting to climate change, for example by means of suitable tree species and forest structures, is a challenge that has to be addressed, because only a forest that is able to adapt can continue to provide its diverse services in the future.

1.1 Forest area

Roberto Bolgè, Fabrizio Cioldi, Cristiana Maineri

- The forest area has increased only slightly in the past decade, mostly at higher altitudes, where it has replaced agricultural use.
- Around a third of Switzerland's land area, or 1.3 million hectares, is covered by forest. The southern side of the Alps is particularly heavily forested, with forest cover of 55%. On the densely populated Plateau, the proportion is around 24%.
- Maintaining the forest area and its spatial distribution will remain a challenge in regions with heavy competition for land such as the Plateau and valley floors.

Figure 1.1.1

Forest boundary above Grächen (VS). The Alpine regions have seen a further expansion of forested area. However, the increase between 2013 and 2022 was smaller than in previous decades. Photo: Roberto Bolgè

Distribution of forest area in Switzerland

At 1.3 million hectares, forests cover 32% of the country's surface area. However, there are big regional differences. The southern side of the Alps is particularly heavily forested, with forest cover of just under 55%, followed by the Jura (40%), Pre-Alps (35%) and Alps (28%). The densely populated Plateau has the lowest proportion of forest, at 24%. Forest cover varies with altitude. The majority of forests are located at altitudes of 600 to 1,800m a.s.l., with very high proportions of forest at over 1,000m a.s.l. On the southern side of the Alps, even altitudes above 600m a.s.l. are over 80% forest. Nationwide, 61% of forest areas are now coniferous and 39% broadleaved (Abegg et al.2023).

Development of forest area

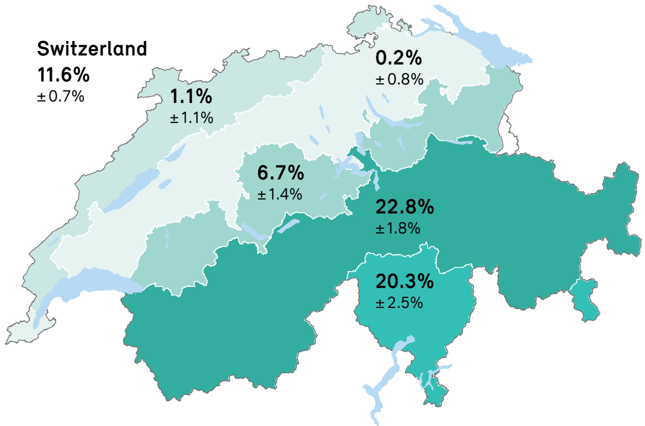
Switzerland's forest area has been increasing for over 150 years. In the past decade, the increase was 23,000 hectares, or 0.2% annually, significantly less than in previous decades. The forest area remained constant in the Jura, on the Plateau and in the Pre-Alps, while it expanded annually by 0.4% in the Alps and 0.3% on the southern side of the Alps (Abegg et al. 2023). Almost 75% of the increase in forest area occurred at altitudes above 1,400m a.s.l., particularly in areas where agricultural use was abandoned and trees were able to grow as a result. The Confederation makes direct payments to support the maintenance of open cultural landscapes and the cultivation of agriculturally valuable areas, thereby creating a framework to counteract the expansion of forest area in these places.

Forest areas also change as a result of deforestation due to land-use conversions, especially in areas with high land-use competition. According to deforestation statistics, an average of 166 hectares of forest were cleared annually between 2013 and 2022 (FOEN Indicator forest and wood). In 2022, deforestation permits were granted for material extraction activities (40%), watercourse corrections (26%) and transport projects (11%). The deforestation was mostly offset by creating an equivalent area of forest, although other forms of compensation are also possible. Instead of replacement afforestation, the cantons may undertake nature and landscape conservation measures, provided they have defined zones in their spatial planning in which the forest area is able to increase. They cantons can also set a static forest boundary outside of building zones as a way of preventing an expansion of forest in certain areas. These areas are to be reviewed and, if necessary, adapted, for example when the structure plan is revised. The cantons can use such measures to intervene in forest development if the principle of forest conservation laid down in the Forest Act (Art. 3 ForA) is no longer adhered to.

The forest conservation instruments, including the prohibition on deforestation and the possibility of issuing exceptional permits under clearly defined conditions, have so far fulfilled their purpose well. Although forest is under pressure, especially on the Plateau, the forest area has been conserved over the decades (Fig. 1.1.2). However, the pressure on forests is likely to increase further as a result of the large amount of land required for buildings and infrastructure and the intensifying competition for land use. It is therefore premature to assume the forest area will always be preserved. Implementing measures to coordinate spatial and forest planning – including ensuring forest conservation – will be an increasingly difficult and challenging task.

Figure 1.1.2

Change in forest area in the five production regions and in Switzerland as a whole from 1983 to 2022.



Source: NFI (Abegg et al. 2023)

Forest functions and services

The importance of forests is not just about their size compared with other elements of the landscape, but also the diverse functions and services they perform for the public (section 3.4). In addition to wood production, they protect settlements and infrastructure from landslides, rockfalls and avalanches; prevent debris and driftwood entering watercourses; provide a habitat for animals and plants; filter rainwater for drinking water; store carbon; and serve as leisure and recreational spaces. All activities in forests and the demands placed upon them are coordinated using forest planning instruments (section 3.5). These increasingly diverse interests are defined as forest functions and services (FOEN 2022a; section 3.4). Forest functions are enshrined in the Federal Constitution as protective, economic and welfare functions (Art. 77 para. 1 Cst.). The Confederation and cantons must ensure that forests can fulfil these functions. In so doing, the cantons observe the principle of multifunctionality as per the Confederation's Forest Policy, i.e. the principle that forests perform multiple functions and services in the same space.

Across Switzerland, protection against natural hazards takes precedence over other forest functions on 44% of the forest area (Abegg et al. 2023). In the Alps and on the southern side of the Alps, this is by far the most important forest function. Wood production is the primary function on 38% of the national forest area, and is particularly prevalent in the Jura and on the Plateau. On 13%, other protection aspects are prioritised, such as nature and landscape conservation, game conservation and drinking water protection. And although recreation is a primary function on only 2% of the forest area, the vast majority of Swiss forests are available for the public to use for recreation or spending time in a way that benefits their health (Abegg et al. 2023). Forests close to settlements are also a key part of communes' green and open space amenities.

1.2 Growing stock

Fabrizio Cioldi, Marjo Kunnala

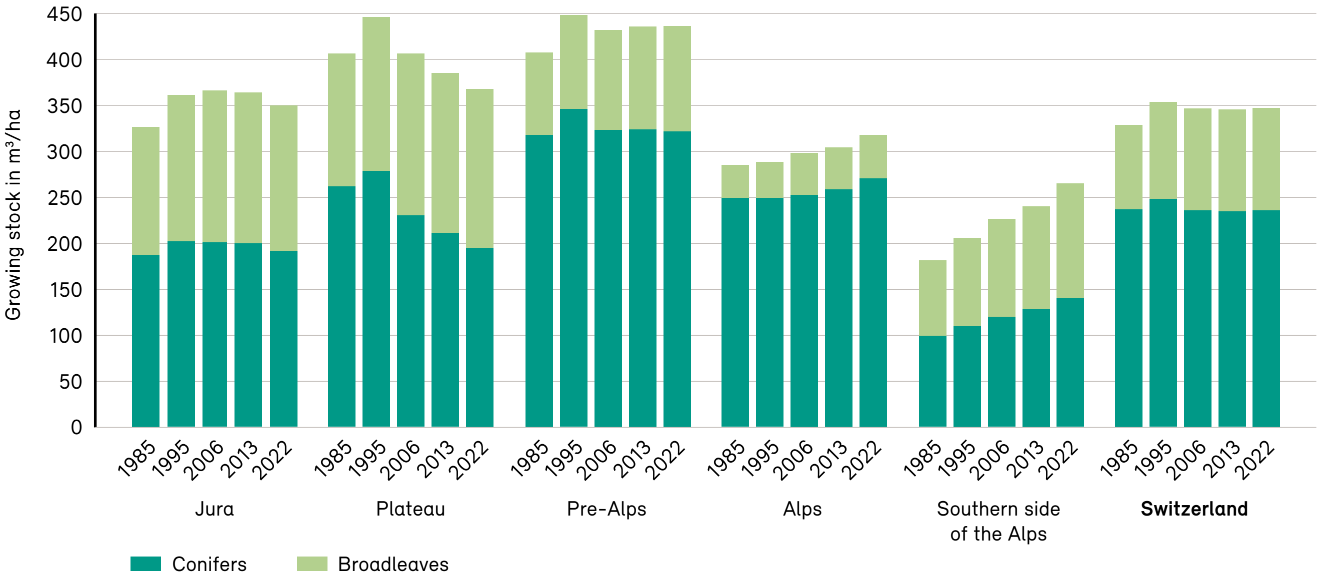
- The growing stock has remained constant over the past decade throughout Switzerland. However, trends varied from region to region. The growing stock increased by 12% on the southern side of the Alps and by 7% in the Alps, while on the Plateau and in the Jura it declined by 5% and 3% respectively.
- The total growing stock of living trees in Swiss forests stands at 420 million cubic metres, or 347 cubic metres per hectare. Conifers make up 68% of the growing stock and broadleaved trees 32%.
- Climate change will have a major impact on growing stock development and future tree species composition. In the Jura and on the Plateau, growing stock declines are expected to continue as a result of increased mortality and salvage logging.

Development of the growing stock
The volume of trees in Swiss forests is regularly recorded in the National Forest Inventory (NFI). This involves surveying all standing and lying trees with a diameter at breast height (dbh) of 12cm or more on the NFI sample plots. A distinction is made between the volume of living trees (growing stock) and of dead trees (deadwood); the sum of the two is the total wood volume. An interim evaluation of NFI5 (2018–22) showed that the total wood volume in Switzerland is 459 million cubic metres (Abegg et al. 2023). Dead trees account for 39 million cubic metres or around 8% of this total (section 4.5). In the past decade, the deadwood volume has increased by a third.

The growing stock of living trees totals around 420 million cubic metres nationwide (Abegg et al. 2023). In terms of area, it averages 347 cubic metres of wood per hectare (Fig. 1.2.1). Since NFI4 (2009–13), the growing stock in Switzerland has remained the same overall, but

Figure 1.2.1

Development of the growing stock of broadleaved trees and conifers in the five production regions and in Switzerland as a whole (including the increase in forest area).



Source: NFI (Abegg et al. 2023)

with regional variations. In the Alps and on the southern side of the Alps, it increased by 7% and 12% respectively, firstly because less wood was used here than grew back, and secondly because new forest has grown on abandoned farmland. In the Jura (– 3%) and on the Plateau (– 5%), the stock declined mainly due to increasing tree mortality and salvage logging required as a result of drought, disease or bark beetle infestations (section 2.5).

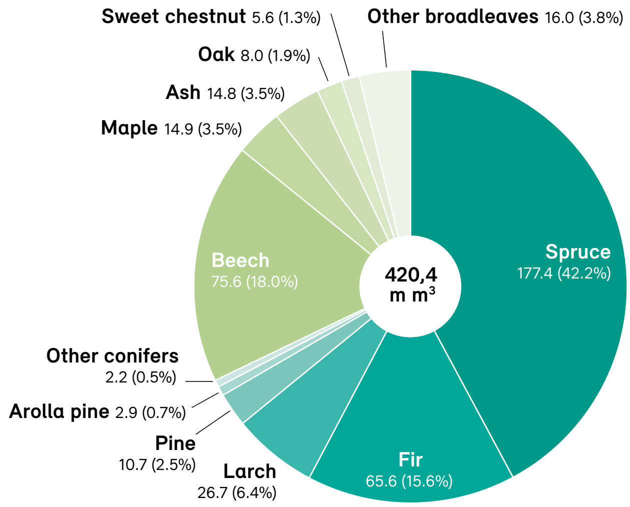
Growing stock proportions by tree species and their regional developments

The growing stock in Swiss forests consists of 68% conifers and 32% broadleaved trees. Spruce accounts for the highest share at 42% (Fig. 1.2.2; Abegg et al. 2023). It is the most abundant tree species in all regions except the Jura. In the Alps, its stock has increased by 6% in the past decade, while on the Plateau and in the Jura it has declined by 15% and 10% respectively. At 18%, beech makes up the second highest proportion of growing stock nationwide. In the Jura, it is actually the top species in this respect (31%), despite a 7% decline in this region. On the Plateau, beech has the second highest share of the growing stock, at 26%. Beech growing stock has increased by 20% on the southern side of the Alps and by 8% in the Alps. The European silver fir accounts for the third highest proportion of the growing stock nationwide (16%), with a relatively high share in the Jura and Pre-Alps especially. In the Pre-Alps and on the southern side of the Alps, fir stocks increased by 9% and 18% respectively.

Larch is in fourth place nationally in terms of growing stock, accounting for 6%. Its share of the growing stock has increased significantly both in the Alps and on the southern side of the Alps. Sycamore is the only tree species that recorded a significant increase in growing stock in all regions, of average 19%. Nationwide, the NFI indicates a 4% share for this species. This makes sycamore – together with ash – the broadleaved species with the second highest share of the growing stock, after beech. The ash growing stock (– 10%) declined sharply due to ash dieback (Rigling et al. 2016). The nationwide stock shares of other tree species such as pine and oak are even lower, at 3% and 2% respectively. Sweet chestnut grows almost exclusively on the southern side of the Alps, where it accounts for a significant 13% of the growing stock. However, for the first time since NFI surveys began, its stock has not increased

Figure 1.2.2

Growing stock (in million m³) and proportions of stock (in %) of the most common tree species.



Source: NFI (Abegg et al. 2023)

over the past decade. The increase in the volume of sweet chestnut due to very low intensity of use was offset by increasing mortality caused by disease, insect infestation, drought and lack of tending (Prospero et al. 2012, Gehring et al. 2020, Conedera et al. 2010).

Tree species composition

The impact of extreme weather is already clearly apparent in forests (section 2.5). It can alter the tree species composition and growing stock to varying degrees depending on the production region. At lower altitudes, where spruce – as a species not native to these areas – has been hit hard, forests are likely to become richer in broadleaved species. In the future, spruce wood – for which there is high demand on the market – will have to be harvested more often from less accessible terrain at higher altitudes, resulting in higher harvesting costs. It is also to be expected that the overall growing stock on the Plateau and in the Jura will decline, as spruce makes up a higher proportion of the total stock than site-appropriate broadleaved species, and this species is set to decline most. In terms of sustainable forest development, this decline in growing stock can be viewed in different ways: it will have a positive impact on ecological criteria such as woody-species and structural diversity, while reducing the availability of economically important tree species such as spruce.

1.3 Age and stand structure

Barbara Allgaier Leuch, Meinrad Abegg, Robert Jenni, Marjo Kunnala

- The proportion of old stands and large-diameter trees has risen in the past decade, which is good news for biodiversity. Conversely, there is an increasing lack of young stands and sufficient regeneration, which could negatively impact forests' protective and wood production functions.
- From an economic perspective, the age structure of Swiss forests is too old. However, from an ecological point of view, more old stands and large-diameter trees are needed. That said, stand structures are often diverse.
- Climate change calls for a further increase in structural diversity, as richly structured forests with sufficient regeneration are less vulnerable and can resume their services more quickly after disturbances.

Age structure of stands

Age structure is an important factor in assessing a forest stand, both ecologically and economically. Different benchmarks are applied depending on the perspective. From an ecological viewpoint, the optimum age structure is based on the stands' natural life expectancy. This is 220 to 250 years for beech stands on the Plateau and 300 to 400 years for spruce stands in the Alps, although individual trees may live significantly longer (Brang and Zingg 2002; Brang and Duc 2002). From an economic perspective, the age structure is based on the economically optimal rotation period, i.e. the stand age at which the yield of the timber sold is highest. In the NFI, the optimum rotation periods for the main tree species have been calculated at 120 to 180 years, depending on the site quality (Bachofen et al. 1988). The economically ideal rotation period is therefore often only half as long as the natural life expectancy of a stand.

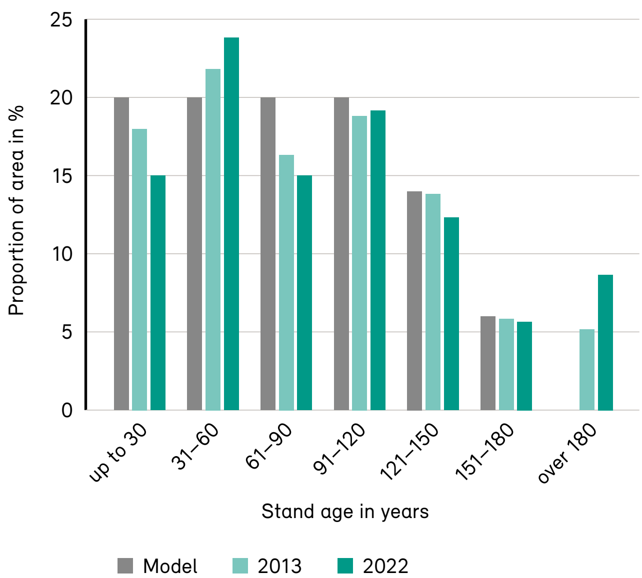
The NFI provides information on the age of forest stands, although only the age of even-aged stands can be meaningfully estimated. These have been extensively regenerated, in Switzerland mostly using the group selection system with natural regeneration (section 4.2). Nationwide, 75% of all stands are even-aged (Abegg et al. 2023). Just under 10% of even-aged forest stands are over 180 years old (Fig. 1.3.1). The highest proportion of stands over 180 years old is in the Alps at 15%, compared with less than 1% on the Plateau. In the past decade, the proportion of old stands has increased everywhere except on the Plateau. Nevertheless, Swiss forests are still too young from an ecological point of view. However, measured by the yardstick of the optimum rotation period for economical wood use, more and more stands are too old (Fig. 1.3.1). At the same time, the proportion of young stands is decreasing. Thus, the forest renewal required for both wood production (section 3.1) and protection against natural hazards (section 5.1) is not occurring.

Diameter distribution of trees

In plenter and continuous cover forests, the age of the trees varies greatly. The stand age is therefore not very meaningful for these forests. Consequently, the distribution of tree diameters is used to assess whether a stand is sustainably structured in terms of its timber yield. The diameter at breast height (dbh) of the trees is measured at 1.3m above the ground. The desired diameter distribution is based on the

Figure 1.3.1

Proportional area of age classes in even-aged forests in 2013 and 2022, compared with the model of economically optimal rotation periods.



Source: NFI (Abegg et al. 2023)

target diameter, i.e. the diameter at which the forest enterprise wants to harvest the trees (Schütz 2002). The diameter survey also provides important information on the habitat potential of the trees (section 4.5) and on the possibilities for wood processing, including in even-aged forests.

As expected, there are many more thin trees in Swiss forests than thick ones. This is because most trees die or are felled before they become old and large (Brändli and Cioldi 2015), with 95% of living trees (> 0cm dbh) no more than 30cm thick (Abegg et al. 2023). While these thinner trees are predominantly broadleaves, conifers make up a higher proportion of the larger-diameter trees. Large broadleaved trees are particularly rare, firstly because many broadleaved species such as birch, hornbeam and rowan do not naturally grow very thick; secondly, because most broadleaved forests occur at lower altitudes, where forests are intensively used and so the trees are felled 'prematurely'.

Sawmills mainly prefer trees with a dbh of 31–60cm, as at least one log of assortment classes 2 (20–29cm mid-diameter) to 5 (50–59cm mid-diameter) can be obtained from their stems. Trees with a dbh of over 60cm are significantly more complex to process. As these trees account for 22% of the growing stock, although they make up only 4% in terms of numbers, a reduction in target diameter/rotation periods in managed forests would be desirable from the point of view of wood production and processing.

From an ecological perspective, however, trees become increasingly valuable for biodiversity as their stem diameter increases because, as habitat trees, they provide a home for many animal and plant species (section 4.5). Giants, i.e. trees with a dbh of over 80cm, are particularly valuable. They are much rarer in Swiss forests than in the natural and pristine forests of Central Europe (Heiri et al. 2012). In the past decade, however, both the number of giants and the number of trees with a dbh of over 60cm has increased in all parts of the country, while the number of stems in the smaller diameter classes has decreased. The promotion of habitat trees is a key aspect of close-to-nature forest management (FOEN 2010).

Stand structure

Besides age structure, the spatial structure of a forest stand, namely the vertical and horizontal structure and the distribution of tree species, is also important for forest development from both an economic and an ecological perspective. In view of increasing disturbances due to climate change, richly structured forests with some regeneration everywhere are to be considered favourable, whereas uniform forests without any regeneration are unfavourable. This applies particularly to protective forests (section 5.1). In addition, richly structured stands offer a variety of habitats in a small area and thus promote biodiversity (section 4.3).

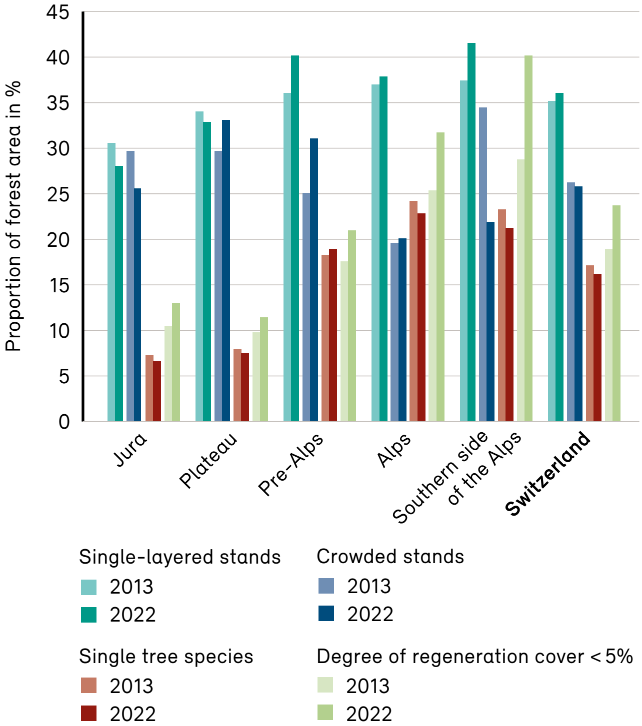
Swiss forests are essentially dominated by three tree species: spruce, beech and fir. However, pure stands, i.e. those consisting of a single tree species, account for only 16% of the forest area. Those with two, three and four or more species each make up around a quarter of the total number of stands. Pure stands are most common in the Alps and on the southern side of the Alps, especially at higher altitudes where only a few tree species naturally thrive. In the Jura and on the Plateau, by contrast, they are rare. Over the past decade, the proportion of such stands has even declined in the Alps and on the southern side of the Alps, as has their average share nationwide (Fig. 1.3.2).

In terms of vertical structure, 36% of stands nationwide are single-layered (Abegg et al. 2023). In such forests, all trees are of roughly the same age and dimensions. Single-layered stands are particularly prevalent in the Alps, the Pre-Alps and on the southern side of the Alps (Fig. 1.3.2). The proportion of such stands in the Pre-Alps and on the southern side of the Alps has increased further in the past decade.

In terms of horizontal forest structure, the trees in a quarter of stands are crowded, meaning that their crowns are shortened and deformed by being in contact with each other. Crowded stands are susceptible to storms and snow load. Also, hardly any light reaches the ground, so young trees are unable to grow. At higher altitudes, regeneration is impaired even in less dense stands, as young trees in the harsher climate need not only light but also warming sunlight for their growth. There has been no change in the proportion of crowded stands in Switzerland as a whole. There are now more on the Plateau and in the Pre-Alps, but fewer in the Jura and on the southern side of the Alps (Fig. 1.3.2).

Figure 1.3.2

Proportional area of selected structural characteristics in the five production regions and in Switzerland as a whole, 2013 and 2022.



Source: NFI

Regeneration

In view of climate change, regeneration under shelterwood, where young trees grow under the canopy of the upper layer, and regeneration in smaller stand openings are becoming increasingly important. Such stands are more resilient as they can regenerate more quickly after a disturbance. However, the trend over the past two decades points in an unfavourable direction. The proportion of forest area with a low degree of regeneration cover (less than 5%) has increased on average across the country, particularly in the Alps and on the southern side of the Alps. Overall, there is hardly any regeneration on 24% of the forest area nationwide, rising to 32% in the Alps and 40% on the southern side of the Alps (section 4.2).

Apart from the degree of regeneration cover, stand structure characteristics have changed little in the past decade. Firstly, trees' long life expectancy means that changes in forests take place only slowly, provided the stands are not affected by large-scale disturbances. Secondly, the processes in individual regions often cancel each other out. Particularly in the region on the southern side of the Alps, however, the changes have been very unfavourable, with an increase in single-layered stands and forests with little regeneration. Here, as well as in other regions of Switzerland, more needs to be done to promote structural diversity and adequate regeneration so that forests can continue to provide their services despite the rapid progression of climate change.

1.4 Carbon stock

Nele Rogiers, Frank Hagedorn, Esther Thürig

- The absolute carbon stock of forest biomass has remained almost constant over the past decade.
- At 269 tonnes of carbon per hectare, Swiss forests have the highest relative carbon stock in Europe. The carbon stock is around 119 tonnes per hectare in living trees and around 150 tonnes per hectare in deadwood, the organic layer and soil.
- Forests and wood use will continue to play a role in tackling climate change, but this will require resilient and climate-adapted forests.

Carbon stock in forest biomass

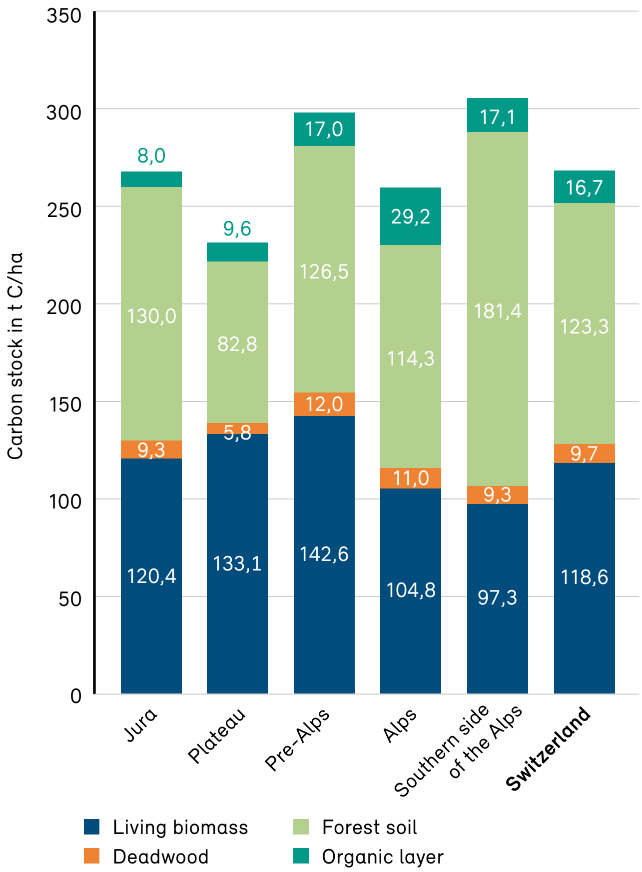
Forests play an important role in the global carbon cycle. The carbon (C) sequestered in forest biomass comprises the biomass of living trees, deadwood, the organic layer and soils. The carbon sequestered in living biomass and deadwood is calculated from NFI data. For each living tree, the carbon in all parts of the tree is added together: stem, thick branches > 7cm, thin branches, leaves, needles and roots (Herold et al. 2019; Didion et al. 2019). To determine the carbon content in the living and dead biomass, a carbon content of 50% of the dry biomass is assumed.

According to these calculations, Swiss forests store around 144 million tonnes of carbon in living-tree biomass. This absolute carbon stock has remained almost constant over the past decade. Living trees store an average of 119 tonnes of carbon per hectare (t C/ha). However, the amount of living biomass varies greatly from region to region. The forests with the largest carbon stocks in living biomass relative to area are located in the Pre-Alps (Fig. 1.4.1), where growing conditions for forests are optimal. Also, because harvesting costs are often high in steep terrain, less wood tends to be harvested than on the Plateau, for example (section 3.1). The relative carbon stock in living biomass is smallest on the southern side of the Alps. Although here too wood use is below average, some of these forests are relatively young and have the lowest increment.

Carbon remains stored in deadwood until the wood has completely decomposed. On average, around 10t C/ha are sequestered in such wood. The proportion of deadwood has increased by 38% across Switzerland in the past decade. The sharpest rise was in the Jura, at over 50%. The relative amount of carbon in deadwood is over 9t C/ha in all regions except for the Plateau (Fig. 1.4.1).

Figure 1.4.1

Carbon stock in tonnes per hectare (t C/ha) in the five production regions and in Switzerland as a whole, in the biomass of living trees (living biomass), deadwood, forest soil and the organic layer, during the NFI5 period (2018–22).



Source: NFI, Nussbaum et al. 2012, Nussbaum and Burgos 2021

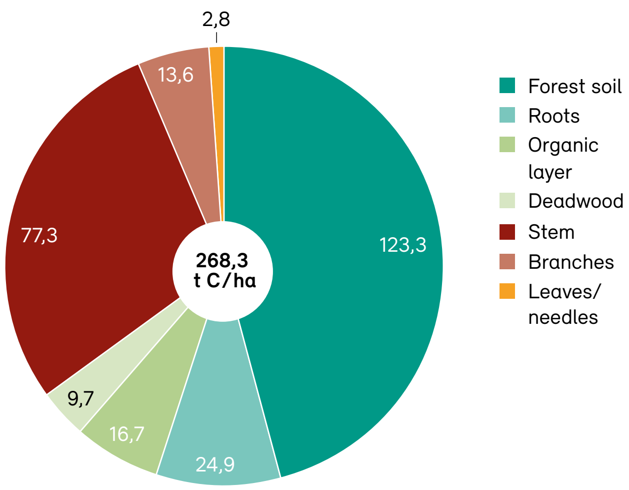
Carbon stock in forest soil

The largest carbon pool in forests is the soil. An analysis of over 2,000 soil profiles, representative of the heterogeneous site conditions in Switzerland, found that forest mineral soil (including the organic layer) stores more carbon than the living biomass – on average 140t C/ha (Fig. 1.4.2). Moreover, forest soils in Switzerland contain around 50% more carbon than those in other Central European countries (Wiesmeier et al. 2013). The reasons for this are the cool and damp climate, close-to-nature forest use and the relatively advanced age of Swiss forests compared with other European countries. Organic forest soils contain even more carbon per area than mineral forest soils, namely 147t C/ha to a depth of 30cm. Despite this, they play a minor role as only 0.3% of forest grows on organic soil.

The carbon content of soil increases at higher altitudes due to the cooler and damper climatic conditions (Fig. 1.4.3). The mineral soils of forests on the southern side of the Alps contain the largest proportion of carbon per hectare (Fig. 1.4.1). This can be attributed to residues from forest fires in recent centuries and to the high levels of iron and aluminium minerals, which protect the humus from decomposition by microorganisms.

Figure 1.4.2

Carbon stock in tonnes per hectare (t C/ha) in living-tree biomass (stem, branches, leaves/needles, roots), deadwood, the organic layer and soils during the NFI5 period (2018–22).



Sources: NFI, Nussbaum et al. 2012, Nussbaum and Burgos 2021

Carbon balance of forests

As they grow, forest trees absorb CO_2 from the air and store the resulting carbon in their biomass. When the biomass decays or is burnt, CO_2 is formed and released back into the atmosphere. If a forest absorbs more CO_2 than it emits, it is a carbon sink. In the reverse case, it is a carbon source. The carbon balance of a forest soil and its organic layer depends on the climatic conditions, the tree species and the physico-chemical properties of the soil. Climate change (higher temperatures and drought) and natural disturbances (storms, beetle infestation and forest fires) may result in higher CO_2 emissions from forest biomass and forest soils.

International climate agreement

Greenhouse gases in the atmosphere have increased by over a third since the 19th century, resulting in changes in the climate (IPCC 2023). In signing the Paris Agreement, Switzerland has made an international commitment to reduce greenhouse gas emissions by 50% by 2030 compared with 1990 levels. This agreement requires all parties to account for the carbon balance of forests and long-lasting wood products. The carbon balance is calculated based on NFI data. Over the past 40 years, Swiss forests have acted as a carbon sink thanks to the increase in growing stock (section 1.2) and the expansion of forest area (section 1.1). However, extreme events can turn these sinks into sources at a local level. For example, within just a few hours in late 1999, Storm Lothar destroyed forest stands that had stored nearly 15 million tonnes of carbon in their living biomass (Rogiers et al. 2015). Most of this wood was subsequently used in construction and therefore did not immediately impact the atmosphere.

Significance of forest as a carbon sink

In the second commitment period of the Kyoto Protocol (2013–20), Switzerland aimed to cut its CO_2 emissions by an average of 15.8% compared with 1990 levels. Taking into account the forest and wood sector's sink effect and the purchase of emission certificates, this reduction target was achieved. During this period, the carbon balance of the forest and wood sector was reduced by 1.8 million tonnes of CO_2 compared with a reference value. Consequently, only 0.7 million tonnes of Swiss forests' total sink effect of 2.5 million tonnes of CO_2 per year could be accounted for.

From a forest policy perspective, increasing forests' sink effect is only desirable as long as the other forest functions are not impaired and sustainable forest development is maintained. Switzerland's current Forest Policy states that forests and wood use should contribute to climate change mitigation. This involves assessing on a case-by-case basis whether it makes sense to increase the carbon stock in forests, e.g. in climate-adapted forests, natural forest reserves or previously cleared forest areas. Resilient, climate-adapted forests are a basic prerequisite for maintaining a sustainable carbon balance in forests.

Figure 1.4.3

Mountain forest soil with a high carbon stock in the organic layer.

Photo: Marco Walser

2
Health and Vitality

Scots pines in the Pfynwald (VS): As a result of more frequent drought, the mortality of this species has been rising in Valais since 1996.

Photo: Marcus Schaub


NO_x
O_3
NH_y

2 Health and Vitality

Marcus Schaub, Stefan Beyeler

Forest health and vitality is a valuable asset that can be jeopardised by environmental influences. Climate change is putting forests under pressure. In Switzerland, the average annual temperature has risen by 2 °C since pre-industrial times. Nitrogenous air pollutants and ozone still exceed critical loads and can make forests even more susceptible to drought. Extreme events such as heatwaves, droughts, hailstorms, storms and forest fires are on the rise, and the effects on forests are manifold. Earlier budburst, the risk of frost and lack of water impair vitality, i.e. the ability of trees to adapt and compete, with beech, fir and spruce particularly affected. Forests are becoming more susceptible to insect infestation and tree diseases, and trees are dying more frequently, in some cases over large areas. Globalised trade in goods is increasingly introducing non-native harmful organisms that can pose a significant threat to the forest ecosystem. Early detection is key to preventing their spread. Other measures can help make forests more adaptable, including planting suitable tree species, promoting site-appropriate mixed forests and increasing genetic diversity. Carefully planned test plantings provide important insights in this regard. A deeper understanding of processes and scientifically sound information about forest health and vitality are needed in order to develop suitable measures for sustainable management. This will enable forests to provide their ecosystem services in the future, even under changed climatic conditions.

2.1 Air pollutants

Sophia Etzold, Sabine Augustin, Sabine Braun, Anne Thimonier, Pierre Vollenweider, Peter Waldner, Marcus Schaub

- Nitrogen deposition exceeds critical loads in almost 90% of forest areas. Increased nitrogen deposition leads to nutrient imbalances in the soil and vegetation and can affect the biodiversity of plants, lichens and soil organisms.
- Ground-level ozone damages the photosynthetic cells in leaves. The ozone dose taken up through the stomata has decreased in beech trees, but it remains above the critical threshold.
- Although nitrogen and ozone pollution has been reduced, it still exceeds the relevant limits in many places and can inhibit forest's growth and drought resistance.

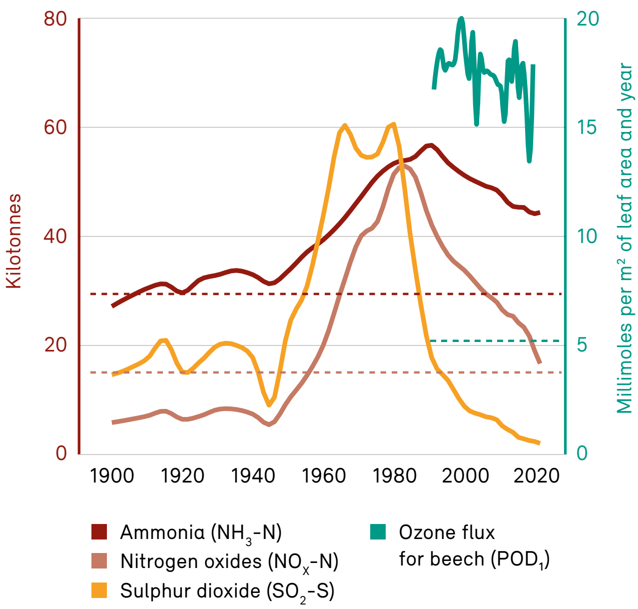
Nitrogen pollution

Thanks to numerous air pollution control measures, pollutant emissions have been falling since 1980 (Fig. 2.1.1). Despite this, federal reduction targets for emissions of nitrogenous air pollutants such as ammonia and nitrogen oxides have not yet been met. Today, around two thirds of these emissions come from agriculture and one third from combustion processes in transport, heating and industry. Nitrogen enters forests as a gas, in aerosols or dissolved in precipitation. As a nutrient, nitrogen initially promotes plant growth, but an oversupply has negative effects on the forest. Nitrogen deposition in Switzerland exceeds the critical limits in almost 90% of forest areas (Fig. 2.1.2). These limits, known as 'critical loads', are the exposure levels below which harmful effects on the environment do not occur according to present knowledge. The critical loads vary depending on the forest stand: 10–15 kilograms of nitrogen per hectare per year (kg N/ha/year) for broadleaved forests and 3–15kg N/ha/year for coniferous forests (Bobbink et al. 2022). Nitrogen deposition in Swiss forests averages 20kg N/ha/year, but can exceed 50kg N/ha/year in some areas (Rihm and Künzle 2023).

Excess nitrogen contributes to nutrient depletion and acidification of forest soils (section 2.2). The soil solutions measured since 1997 in the Intercantonal Forest Observation Programme (WDB) confirm progressive soil acidification due to high nitrogen pollution (Braun et al. 2020a). In addition, the oversupply of nitrogen disturbs the nutrient balance in trees, especially that of the essential nutrients phosphorus and potassium. A decline in phosphorus has been demonstrated both in European forests (Jonard et al. 2014, Talkner et al. 2015) and in Switzerland (Braun et al. 2020b). This makes trees less resistant to drought, frost and pest infestation (Bobbink et al. 2022). Excess nitrogen also impairs the symbiotic community of trees with mycorrhizal fungi (Peter et al. 2001). These colonise the roots and play a key role in supplying the trees with nutrients from the soil and water. Increasing nitrogen pollution reduces the colonisation, growth and species spectrum of mycorrhizal fungi (de Witte et al. 2017, Suz et al. 2021).

Figure 2.1.1

Air pollutant emissions from 1900 to 2020 and development of ozone flux (POD_1) for beeches (green). The dashed lines correspond to the targets set out in the Federal Council's 2009 Air Pollution Control Strategy for NO_x and NH_3 and the critical loads for ozone set by UNECE.



Sources: CEIP 2023, Meteotest ozone mapping based on Braun et al. 2014

The fertilising effect of nitrogen initially boosts tree growth, with maximum increment occurring at depositions of 18–25kg N/ha/year (Etzold et al. 2021). However, this increased growth rate alters the ratio of above- and below-ground biomass as well as the internal structure of the wood, which in turn weakens the trees' stability (Braun et al. 2023a). Nitrogen deposition of over 30kg N/ha/year inhibits tree growth (Etzold et al. 2020). This effect is intensified by simultaneous drought (Braun et al. 2017). Nitrogen pollution also changes the species composition and diversity of the understorey as well as of the algae and lichens in the forest. Common, nutrient-loving species spread further, displacing rarer specialist species.

Ozone pollution

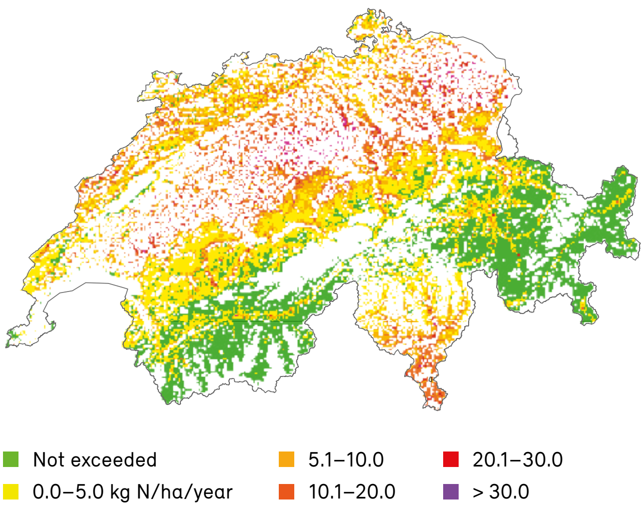
Ozone is a colourless and odourless trace gas in the atmosphere that is formed near the ground from nitrogen oxides and volatile organic compounds (VOCs) when there are high levels of solar radiation. Ozone is toxic to plants and humans. In Switzerland, the threshold value of 120 micrograms per cubic metre set for human health is exceeded for several hundred hours per year (FOEN 2022b). While peak concentrations have been falling since 1980, average pollution levels are on an upward trend. By far the highest ozone levels in Switzerland are recorded in Ticino.

Ozone damages the photosynthetically active cells in leaves. This results in premature leaf ageing, which becomes visible through discolouration of the foliage. Characteristic symptoms such as small dots on leaves or the marbling of needles also indicate ozone stress. The cytotoxin also slows down the trees' growth. Increment data from the WDB confirm a substantial decline in the growth of beech and spruce trees in Switzerland as a result of ozone pollution (Braun et al. 2022).

Ozone is harmful to plants only when it is taken up through the stomata in the leaves. It is therefore the accumulated ozone dose absorbed, or ozone flux, that is key to assessing the risk, not the atmospheric ozone concentration. The ozone flux depends on the environmental conditions. When the air is dry and soil water availability is low, for example in summer, the plant closes the stomata to prevent water loss. The plant therefore takes up little or no ozone, despite the high concentration in the air. The extent of ozone flux varies depending on the tree species. In fumigation experiments, a critical ozone flux level of 5.2 millimoles per square metre of leaf area per year (mmol/m^2/year) was calculated for beech trees. This results in an average growth reduction of 4% for this species. For spruce, the critical level was calculated at 9.2mmol/m^2/year, with a 2% growth reduction (CLRTAP 2017a). The ozone flux in beech has tended to decrease slightly since 1991, but is still well above the critical level (Fig. 2.1.1).

Figure 2.1.2

Exceedance of the critical loads for nitrogen deposition from the air in kilograms of nitrogen per hectare per year (kg N/ha/y), for the year 2020.



Source: FOEN 2023, Meteotest

2.2 Soil

Katrin Meusburger, Simon Tresch, Janine Schweier, Sabine Braun, Sabine Augustin, Stephan Zimmermann

- The increasing frequency of drought years with limited soil water availability is a stress factor for forests.
- Soil acidification due to excessive nitrogen deposition has progressed further. This reduces the availability of important nutrients such as calcium, magnesium and potassium, while also releasing toxic aluminium.
- Another threat is physical stress during forest management, such as soil compaction caused by heavy forestry machinery. This could be avoided with adapted management methods.

Water availability in soil

Soil is the basis of life for forests and is not renewable on a human timescale (Alewell et al. 2015). Forest soil supplies the forest with water and nutrients. Both functions are being impaired by climate change, air pollution (section 2.1) and physical stresses such as compaction by forestry machinery. Soil protection is therefore a key issue.

The availability of water in the soil has been severely limited in recent drought years (Meusburger et al. 2022). One measure of the water available to vegetation at a site is the ratio of actual transpiration (Ta) to potential evaporation (Tp). The lower the Ta/Tp ratio, the lower the actual transpiration of the vegetation, which indicates drought stress due to insufficient water availability. In the drought years 2003, 2015, 2018 and 2022, drought stress occurred particularly in the low-elevation areas of Valais, but also in the Jura range, Klettgau and Ticino (Fig. 2.2.1).

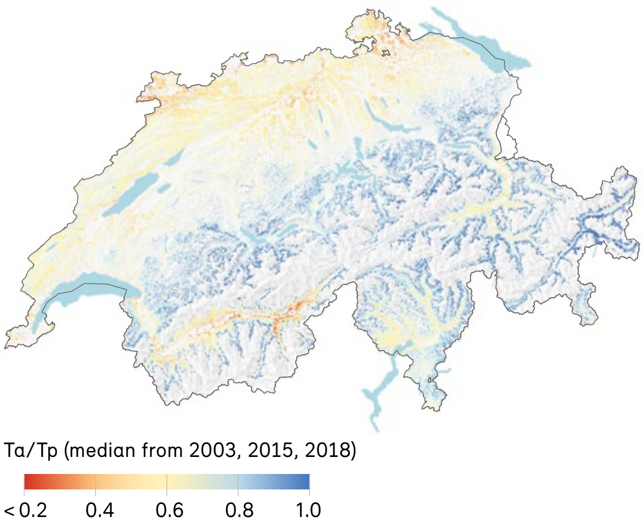
Nutrient availability and soil acidification

A key indicator of nutrient availability in the soil is base saturation, i.e. the percentage of the nutrients calcium, magnesium, potassium and sodium in the soil's total exchange capacity. The nutrient uptake of the trees depends on this capacity. Generally acidic soils on the Plateau and on the southern side of the Alps have medium to low base saturation values of between 15% and 40% in the topsoil, depending on the nature of the soil-forming rocks. On calcareous rocks such as those found in the Jura or the Limestone Alps, the base saturation is higher, averaging over 40% (Fig. 2.2.2a).

Forest soils acidify when the acid deposition from the atmosphere is greater than the weathering rate, i.e. the supply of nutrients through weathering in the soil. As acidification progresses, the pH value of the soil decreases, nutrients are washed out (leached) and, as a result, the base saturation also declines. The Intercantonal Forest Observation Programme (WDB), which has been running since 1984, observed acidification and a decline in base saturation at all sites (n = 176) between 2005 and 2016. In the lime-free soil layers, the pH value dropped by 0.22 units, while the base saturation in the topsoil decreased by an average of 2.9%. The results show that the process is related to excessive nitrogen deposition (Fig. 2.2.2b). This is because, when excess nitrogen is leached out of the soil by rain as nitrate, nutrients are washed away at the same time. This reduces nutrient availability (Braun et al. 2020a), which can result in malnutrition of the trees (Braun et al. 2020b).

Figure 2.2.1

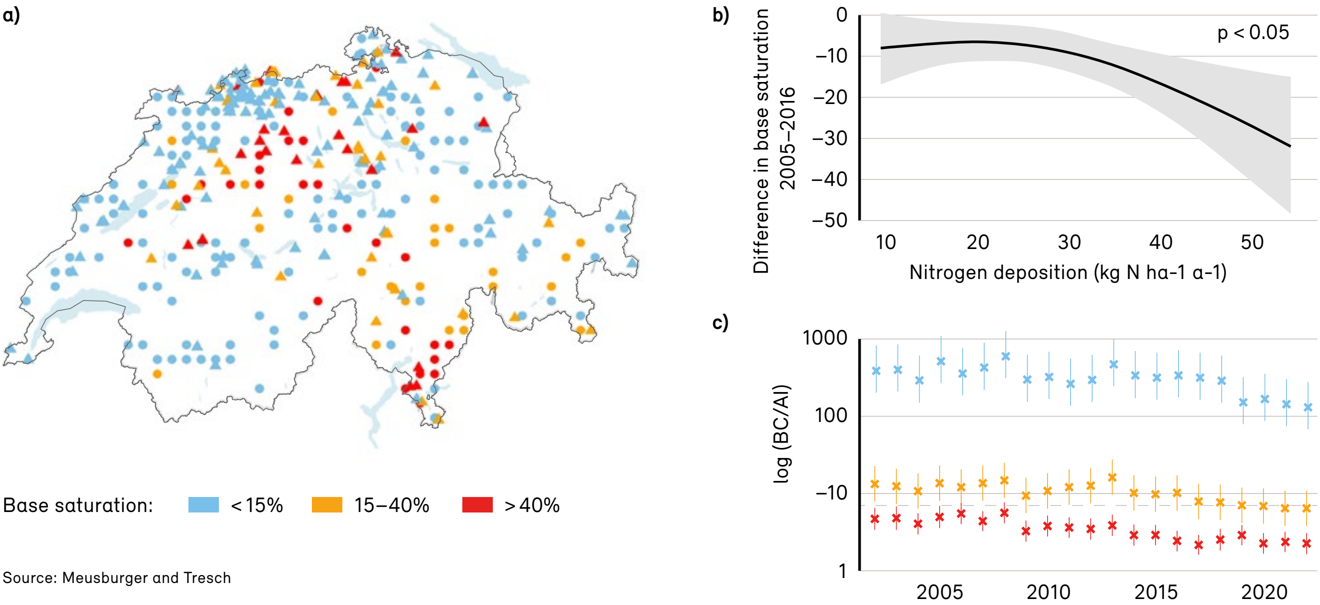
Modelled ratio of actual to potential transpiration (Ta/Tp) in July and August of the three drought years 2003, 2015 and 2018.



Source: Meusburger et al. 2022

Figure 2.2.2

a) Base saturation in topsoil (0–40cm) on an 8×8km grid (n = 172, dots) and at WDB sites (n = 213, triangles), b) Modelled correlation between the difference in base saturation between 2005 and 2016 and the nitrogen deposition (n = 485 lime-free samples from 123 WDB sites), c) Average BC/Al ratio in soil water with varying base saturation (n = 45 WDB sites and n = 9 Long-Term Forest Ecosystem Research [LWF] sites), from 2000 to 2023.



Source: Meusburger and Tresch

Soil acidification also releases toxic aluminium, which inhibits root growth. The ratio between the base nutrient cations (BC) and inorganic aluminium (Al) in the soil solution is also used as a measure of soil acidification. The declining BC/Al ratio over the past few years thus also highlights the progressive soil acidification occurring in many forest soils in Switzerland (Fig. 2.2.2c). A low BC/Al ratio is associated with the weakening of tree vitality parameters such as growth (Sverdrup and Warfvinge 1993), with a shallow rooting depth (Braun et al. 2005) and with increased susceptibility to windthrow (Braun et al. 2003).

Physical soil protection

Physical soil damage such as erosion and compaction is caused, among other things, by the improper use of heavy forestry machinery. Damage can be reduced by alternative working methods, strategic scheduling and suitable machine technology in forest management (Lüscher et al. 2019). For example, lowering the tyre pressure from 3.5 bar to 2.5 bar significantly reduces peak pressures in the soil and rutting. The use of bogie tracks, which are fitted over the wheels like mobile caterpillar tracks, has also proved effective. They transmit traction forces with less slippage and tear up the ground less, while also reducing rutting. During fully mechanised softwood harvesting, fallen branches can be laid out as brash mats on the skid trails. This transfers the traction forces to the mat and protects the soil. A good, long-term network of forest roads is key to protecting soil during timber harvesting.

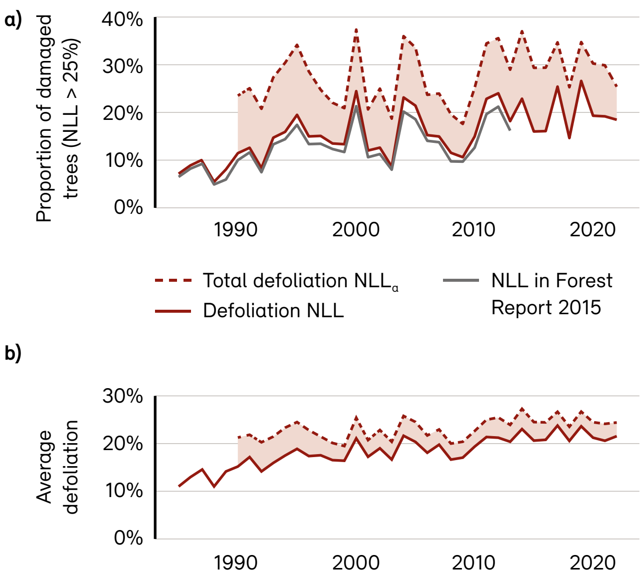
2.3 Condition of tree crowns

Stefan Hunziker, Sabine Augustin, Sabine Braun, Simon Tresch, Christian Hug, Peter Waldner, Arthur Gessler

- Defoliation in Swiss forests is tending to increase, with strong annual fluctuations. This is apparent from the results of the Sanasilva Inventory and the Intercantonal Forest Observation Programme (WDB).
- An increase in mortality is observed in some tree species, this also being subject to annual fluctuations.
- The annual fluctuations can be partly explained by extreme events such as storms or drought years. The upward trends seen over the past ten years could intensify further if the extreme events predicted by climate models become more frequent.

Figure 2.3.1

Development of defoliation (all tree species) from 1985 to 2022, including defoliation from unknown cause (NLL) and total defoliation (NLL_a). The coloured areas show defoliation from known causes. a) Proportion of damaged trees (NLL > 25%). The defoliation from the Forest Report 2015, based on different data evaluation and quality control, is shown as a comparison (grey line). b) Development of average defoliation in all tree species according to NLL and NLL_a. (NLL = needle and leaf loss).



Source: Sanasilva Inventory

Defoliation

Tree foliage is a telling indicator of forest condition. Defoliation in Swiss forests has been systematically recorded every summer since 1985 in the annual Sanasilva Inventory. Around 1,000 trees on (currently) 49 sample plots of the National Forest Inventory (NFI) are visually assessed using a standardised procedure. The plots are spread across the country on a square 16×16km grid.

Defoliation is expressed as the percentage of needle or leaf loss (NLL) in a crown that cannot be explained by a known cause. The benchmark is a tree with full foliage, of the same age at the same site. Since 1990, total defoliation (NLL_a) has also been recorded. This includes the extent of defoliation from known causes, i.e. wind breakage, hail, snow breakage or flowering effects such as mass flowering and seed production. Still living trees with over 25% defoliation are classed as 'damaged', those with over 60% defoliation as 'severely damaged'. The Sanasilva Inventory is part of ICP Forests (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests), which collects comparable data in almost all European countries (Eichhorn et al. 2020). Using similar methods, 184 additional plots containing over 12,500 beech, spruce and oak trees have been recorded in the Intercantonal Forest Observation Programme (WDB) since 1984 (2008 in the case of oaks). The WDB plots were specifically chosen with a view to investigating other ecological influencing factors. Direct comparisons of the absolute values with the geographically representative Sanasilva Inventory are therefore not possible.

Development of crown condition

The results of the Sanasilva surveys show that the proportion of damaged trees (NLL > 25%) has increased on average across all tree species over the long term (Fig. 2.3.1a). From 1985 to 1989, this proportion was usually well below 10%. From 2010, it regularly exceeded 25%, peaking at almost 27% in 2019. The development over time is comparable in conifers and broadleaved trees. The long-term upward trend in average defoliation has been even more pronounced (Fig. 2.3.1b). The proportion of severely damaged trees (NLL > 60%) has remained below 3% over the entire observation period, but has been rising at a low level since around 2004.

The proportion of damaged trees calculated on the basis of total defoliation NLL_a is naturally higher for (Fig. 2.3.1a) as this also includes known causes. These parameters do not allow any reliable conclusions to be drawn about tree health. Only a differentiated analysis of the crown condition enables more precise statements to be made about the long-term trends. For example, there are often large annual fluctuations in the total defoliation. However, the long-term trend towards a higher proportion of damaged trees is less pronounced. The strong annual fluctuations point to the impact of extreme events such as storms and drought years, although these usually affect defoliation with a delay of one or more years (Frei et al. 2022).

The total defoliation on WDB plots is shown in Figure 2.3.2a for beech, spruce and oak. The annual fluctuations are due to weather influences such as drought and late frost and, in the case of beech, also to fruiting and nutrient deficiencies (Braun and Flückiger 2013). It is striking that the proportion of severely damaged tree crowns rose sharply in all three tree species after the very dry summer of 2018 (Fig. 2.3.2b).

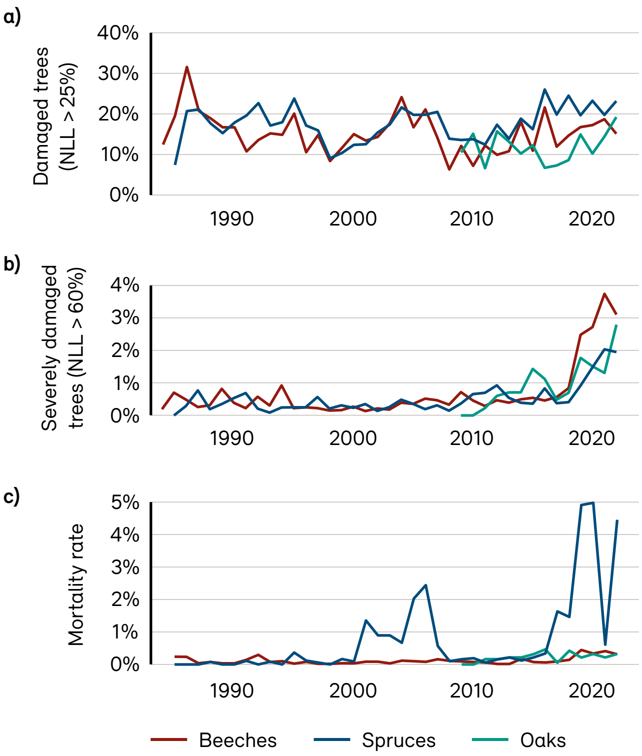
Development of tree mortality

The mortality rate of trees on the Sanasilva plots is recorded as a further indicator of forest health (Fig. 2.3.3). The data for conifers do not show any long-term trend, but do reveal a high mortality after storms or periods of drought. The mortality rate of broadleaved trees rose between 2009 and 2022. The increase observed in Swiss forests was mirrored in studies in other European countries (Senf et al. 2018).

A sharp rise in spruce and beech mortality was also seen on the WDB plots after the drought year 2018 (Fig. 2.3.2c; Braun et al. 2021, Tresch et al. 2023). In the case of oaks, which have only been recorded since 2008, there are large annual fluctuations, with no long-term trend discernible.

Figure 2.3.2

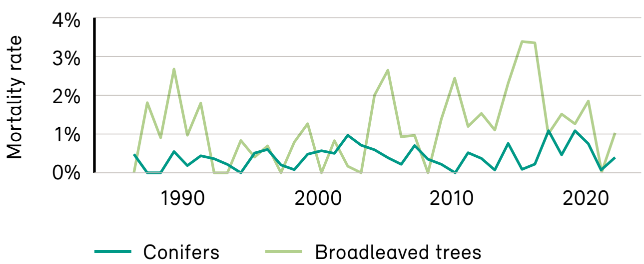
Development of defoliation (NLL) and mortality in beech, oak and spruce from 1984 to 2022. a) Proportion of damaged trees (NLL > 25%). b) Proportion of severely damaged trees (NLL > 60%). c) Proportion of dead beech, oak and spruce trees. (NLL = needle and leaf loss).



Source: WDB

Figure 2.3.3

Mortality rate of conifers and broadleaved trees from 1985 to 2022.



Source: Sanasilva Inventory

2.4 Forest damage

Valentin Queloz, Marco Conedera, Gianni Boris Pezzatti, Michael Sautter, Sophie Stroheker, Meinrad Abegg, Sabine Braun, Simon Tresch, Aline Knoblauch, Simon Blaser

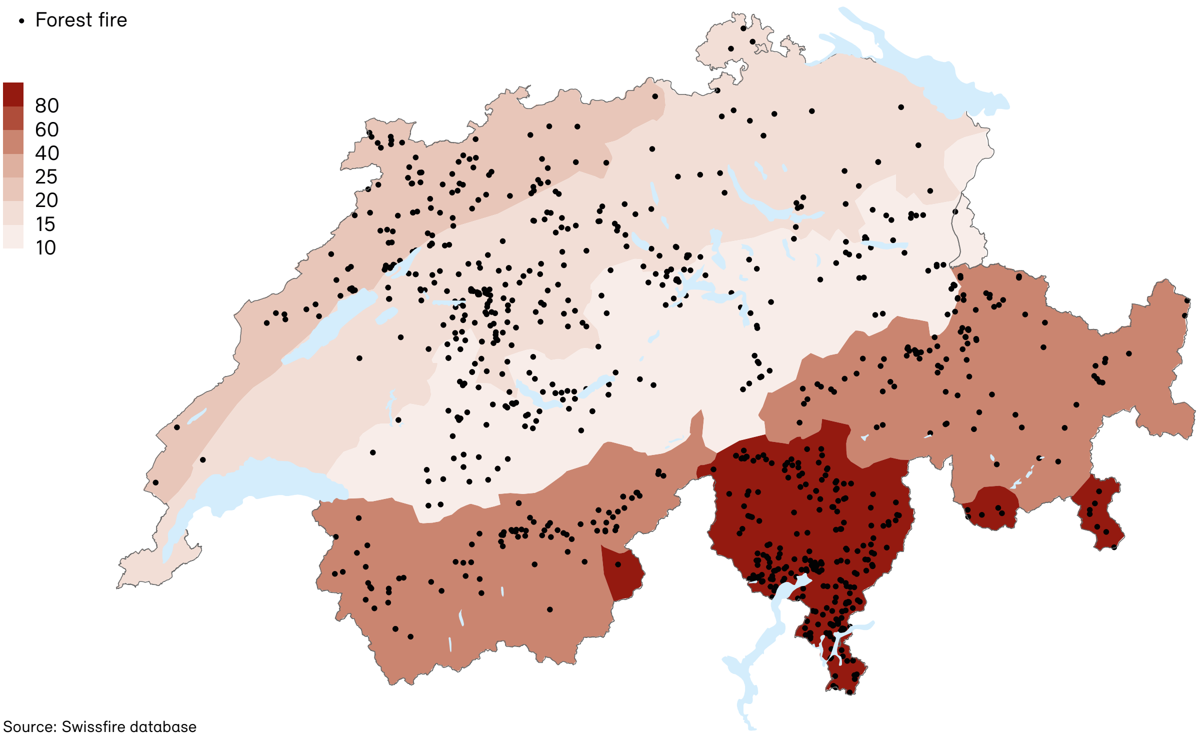
- Higher temperatures and more frequent droughts are increasing the risk of forest fires. The combined effects of such abiotic factors and of native and non-native harmful organisms are generating new types and dimensions of damaging events.
- Forest trees are weakened in many places, and single trees – or in some cases large areas of forest – have died as a result of climate change, forest fires, hail, complex tree diseases and the pressure of invasive species.
- Tree species and provenances that are more resistant to climate change and harmful organisms are essential to ensure that forests can continue to provide their services.

Forest fires

Between 2015 and 2022, an average of 114 forest fires were recorded annually in Switzerland (Fig. 2.4.1), with an average burnt area of 143.3 hectares. The increase compared with the decade from 2005 to 2015 (98.3 forest fires, 94.7ha per year) can be explained firstly by the fact that forest fire data have only been systematically recorded in all cantons since 2008, and secondly by the increase in dry periods. Most fires (57%) take place during the growing season from May to November. However, most of the burnt area (88%) is attributable to winter surface fires. On average, 24% of fires in the growing season and 13.7% throughout the year are caused by lightning strikes. These tend to smoulder underground, but only affect small areas of around 0.2 hectares on average.

Figure 2.4.1

Number of forest fires per 1,000km² of flammable area from 2015 to 2022.



Source: Swissfire database

Totalling 352 hectares per 1,000 square kilometres (ha/1,000km^2) of flammable area, the burnt area on the southern side of the Alps was many times larger than in the other regions of Switzerland (Alps: 8ha/1,000km^2, Jura: 5ha/1,000km^2). Major forest fires covering over 50 hectares only occurred on the southern side of the Alps: the fire caused by negligence on Monte Gambarogno on 30 January 2022 with a burnt area of 196 hectares, the fire in Verdasio-Centovalli on 23 March 2022 (87ha, railway-related), the two fires on 27 December 2016 in Mesocco (119ha, arson) and in Chironico (114ha, negligence) and the fire in Isone on 2 December 2016 (180ha, army-related), in which the majority of the burnt area (160ha) was grassland. Extended dry periods increase the number of forest fires (Swissfire database). The risk from forest fires remained largely under control thanks to rapid intervention and enhanced prevention measures. The regional and cantonal forest fire plans and strategies were supplemented by the introduction of a national forest fire hazard information system. This daily, nationwide alert mechanism has bolstered forest fire prevention.

Heat, drought and windthrow

Forest damage is increasing as a result of extreme climatic events such as heat and drought as well as long-term water shortages. Drought causes direct signs of decline and weakens the resistance of trees to harmful organisms such as insects and fungi (section 2.5). The interim results of the fifth National Forest Inventory NFI5 (2018–26) show that tree vitality has declined significantly in recent years due to water shortage or drought (Abegg et al. 2023). The proportion of damaged areas attributable solely to drought is 7.2% (± 2%). Mortality owing to drought damage increased significantly on the approximately 200 plots of the Intercantonal Forest Observation Programme (WDB) in the years 2018–22 compared with the long-term average for 1984–2018: by a factor of ten for spruce (Tresch et al. 2023) and a factor of three for beech (Braun et al. 2021).

In addition to drought, heat and forest fires, windthrow and hail also cause significant damage to forests. For example, winter storm Eleanor (Burglind) brought down 1.3 million cubic metres of wood in 2018. Devastating summer storms, especially hailstorms, have occurred more frequently in the past decade compared with the previous period 2003–12. Several exceptionally strong hailstorms hit Switzerland in July 2021. The impact of the hailstones caused extensive bark flaking and tree-top breakage on a local scale, weakening conifers in particular and resulting in the death of entire stands in some places (Dubach et al. 2023). A significant increase in windthrow and broken stems was observed on the WDB's beech and spruce plots (Braun et al. 2023b).

Native insects

Following abiotic disturbances in the form of winter storms Eleanor (Burglind) and Vaia (Adrian) and the hot summers of 2018, 2019 and 2020, many parts of Switzerland were hit by a large-scale bark beetle infestation. The disturbances generated large quantities of damaged wood, which provided ideal breeding conditions for the spruce bark beetle *(Ips typographus)*. The result was a mass proliferation of this species, which peaked in 2019 when over 1.5 million cubic metres of spruce wood were infested nationwide (Stroheker et al. 2020). The infestation is reflected in the interim results of NFI5, which show a 15.4% decline in spruce stemwood stocks on the Plateau compared with NFI4 (2009–17).

In 2022 and 2023, intensive and widespread outbreaks of the native leaf blotch miner moth *(Acrocercops brongniardella)* were recorded in the canton of Valais. Until then, it had been considered inconspicuous. The leaf blotch miner moth causes damage through the mining activity of its larvae, which turns oak leaves brown and causes them to drop prematurely (Dubach et al. 2023).

Native fungal and bacterial diseases

Not all harmful organisms benefit from climate change and extreme events. Although stressed trees are generally less resistant to fungal infections, dry and hot summers inhibit the development of many fungi. While the long-term trend is for some fungal diseases such as Armillaria infection, pine tip blight *(Diplodia sapinea)* and charcoal canker (*Biscogniauxia* spp.) to increase with climate change, other diseases and pathogens are tending to be suppressed, such as the oomycetes of the genus *Phytophthora* and Swiss needle cast *(Nothophaeocryptopus gaeumannii)* (Sturrock 2012).

Figure 2.4.2

a) Slime flux symptoms on oak trees in the canton of Basel-Landschaft. b) Sampling by Swiss Forest Protection (WSS) to detect AOD-causing bacteria and Phytophthora*. Photos: Simon Tresch (IAP)*

Some fungal diseases are highly variable from year to year owing to weather conditions. The pathogen that causes pine tip blight, for example, does very well in heat and drought. If a hail event helps the fungus to enter the shoots, it develops rapidly in a subsequent drought and can kill the pines in a single growing season.

A striking phenomenon in recent years has been the increase in slime flux in trees. This can be caused by fungi, fungus-like microorganisms of the genus *Phytophthora* or bacteria. In 2017, for example, acute oak decline (AOD) caused by various types of bacteria was detected in sessile oaks for the first time in Switzerland (Fig. 2.4.2). Since then, several sites with affected trees have been identified on the Plateau and in the Jura. AOD, in combination with the two-spotted oak buprestid *(Agrilus biguttatus)* and other environmental factors, can cause the death of infected oaks (Dubach et al. 2023).

Non-native harmful organisms

As well as native harmful organisms, introduced invasive species also pose a threat to Swiss forests. The Asian long-horned beetle (ALB, *Anoplophora glabripennis*), which has no natural enemies in Europe, is particularly dangerous. It attacks various broadleaves and can kill them within a few years. Five infestations have been recorded on open land in Switzerland since autumn 2011. Four of these are now considered to have been eradicated thanks to systematic control and monitoring. The largest outdoor outbreak to date was discovered in the canton of Lucerne in summer 2022.

Another insect pest, the northern bark beetle *(Ips duplicatus)*, was detected in the St Gallen Rhine Valley in 2019. While this particular species targets conifers, four new non-native broadleaf bark beetles were discovered in Ticino in 2022. Their damage potential is still largely unknown (Dubach et al. 2023). Other non-native forest insect pests recorded for the first time were the elm zigzag sawfly *(Aproceros leucopoda)* in the canton of Zurich in 2017 and the Douglas fir needle midge of the genus *Contarinia* in 2022 (Beenken et al. 2018, Blaser et al. 2023). Originating from China, the chestnut gall wasp *(Dryocosmus kuriphilus)* has been causing considerable damage to sweet chestnuts in the region on the southern side of the Alps for years. The Asian parasitoid wasp *Torymus sinensis* has now established itself as a natural enemy of the chestnut gall wasp (Beenken et al. 2018).

Ash dieback, which is caused by the East Asian fungus *Hymenoscyphus fraxineus*, was first detected in Switzerland in 2008. The disease results in very high mortality in young ash trees. While adult ash trees survive for longer, over time some of them do fall victim to dieback or, secondarily, to the honey fungus (Armillaria). In 2022, 168,489 cubic metres of ash wood had to be salvage logged, a record quantity for the period 2016–22. This is reflected in the interim results of NFI5, which already showed a slight decrease in ash growing stock in the Jura and on the Plateau (Abegg et al. 2023). Around 2–5% of ash trees are resistant. These specimens should be conserved so that they can pass on their resistance to future generations (Dubach et al. 2023).

In addition, several new fungal and bacterial pathogens that are not yet considered invasive have been described or detected in the past decade: the bacterium *Pseudomonas syringae* pv. *aesculi* on horse-chestnut, the fungus *Petrakia liobae*, which attacks beech leaves, the hornbeam blight *Cryphonectria carpinicola*, three new Asian powdery mildew fungi and the ascomycete *Microstrobilinia castrans*, which attacks male spruce catkins and renders them infertile. The invasive fungus *Cryptostroma corticale*, which causes sooty bark disease in maples, has also become more significant with climate change and has been increasingly detected in Switzerland. It kills the cambium (the tree's growth layer) and forms a sooty layer of fungal spores on the stem. These can cause allergic reactions in humans.

Phytosanitary measures must be taken in order to prevent non-native harmful organisms from being introduced, spread and doing damage to forest. In Switzerland, this is the responsibility of the Swiss Federal Plant Protection Service (SPPS), which every year checks around 2,000 imported containers with wooden packaging materials for especially dangerous harmful organisms. Raising public awareness is also key to the early detection of an infestation. In addition, specialist courses are organised for staff working in the horticultural sector. Moreover, the Confederation, cantons and WSL developed a risk-based territory surveillance programme for certain harmful organisms between 2020 and 2022.

Combined effects and their consequences

Combined effects of abiotic and biotic factors can result in new types and dimensions of damaging event. For instance, the effects of drought on bark beetle infestation are significantly higher in areas with high nitrogen deposition, especially at lower altitudes and in spruce stands on sites where spruce does not naturally occur (Tresch et al. 2023). However, combined effects can also occur between biotic factors alone. Thus, the chestnut gall wasp in combination with the chestnut blight caused by *Cryphonectria parasitica* fungus can increase mortality in sweet chestnuts.

2.5 Impact of climate change on health and vitality

Matthias Saurer, Arthur Gessler, Charlotte Grossiord, Meinrad Abegg, Sabine Augustin, Marcus Schaub

- As hot, dry years become more frequent, forests are placed under stress. Even tree species previously considered drought-resistant are suffering as a result.
- Interim results of the fifth National Forest Inventory show an increase in damaged trees. The main causes are insects and pathogens as well as windthrow and loss of vitality after drought.
- The Federal Office for the Environment (FOEN) and the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) have developed tools for selecting tree species in a changing climate. Key measures include promoting mixed forests and increasing the genetic diversity of forests.

High temperatures and low rainfall

Owing to climate change, the average annual temperature in Switzerland rose by 2 °C in the 30-year period 1993–2022 compared with the pre-industrial period 1871–1900 (MeteoSwiss 2023). Extremely hot and dry years have also become more frequent in recent years. Most of the temperature and drought records set in summer 2003 have already been broken several times, despite that summer being considered exceptional. The seven hottest years on record have been since 2010. 2018 in particular stands out, setting a new annual record for temperature in the summer months – hotter than any year since measurements began in 1864. The high temperatures have been accompanied by very low rainfall. These droughts have been exceptionally severe even in the context of the past 2,100 years, as reconstructed from tree rings (Büntgen et al. 2021), and have led to widespread tree damage such as defoliation (section 2.3). The rapid succession of dry and hot summers also makes it difficult for forests to recover.

Impact on trees

The changing climate also has other effects on forests. For example, many broadleaved trees are sprouting earlier, although the risk of late spring frosts remains high or is even increasing (Vitasse et al. 2018). Tree species that recover quickly from frost damage could benefit in the future (Baumgarten et al. 2023). The longer growing season could be advantageous for species such as the downy oak that can maximise their photosynthesis in spring and autumn and so compensate for reduced carbon uptake during the summer (Grossiord et al. 2022). However, a longer growing season is not necessarily conducive to growth, as this depends primarily on the number of wet days (Etzold et al. 2022). The combination of a lack of water in the soil, very high temperatures and dry air is having an increasing impact on forests. Particularly affected are spruces at low altitudes, which can die suddenly due to lack of water (Arend et al. 2021; section 2.3).

Even tree species previously considered drought-resistant, such as beech and European silver fir, are suffering from the increasingly dry conditions. In beech trees, small air bubbles form in the water-conducting vessels, resulting in embolism. Consequently, entire sections of the crown can no longer be supplied with water and die off (Braun et al. 2021, Schuldt et al. 2020). This is not only determined by the current year, but also by how dry it was in previous years (Klesse et al. 2022). Winter moisture also plays a major role, especially at drier sites (Goldsmith et al. 2022). Firs react very sensitively to a high vapour pressure deficit in the air. This is particularly elevated in very hot and dry air (Etzold et al. 2022), a factor that should be given greater consideration when selecting tree species. The vapour pressure deficit is an important criterion in the classification of sites from 'dry' to 'moist/fresh' (Braun et al. 2023c).

Prolonged or repeated periods of stress can result in a lack of carbon in trees as they close their stomata during these periods in order to save water. This impairs the trees' vitality, which reduces their leaf or needle mass in the long term. In addition, the trees lack energy for defence mechanisms such as resin production, making them more susceptible to insects and pathogens. Long-term studies on Scots pines in the Pfynwald (VS) show that a lack of water is responsible for the problems faced by this species (Bose et al. 2022). The Scots pine is therefore under pressure from climate change in inner Alpine valleys. In the long term, their stands could be replaced by more drought-resistant species such as the downy oak.

Stand vitality and health

The National Forest Inventory (NFI) records the growth of Swiss forests at regular intervals. The interim results of NFI5 (2018–26) are now available for the years 2018–22 (Abegg et al. 2023). Forestry agencies were surveyed on stand health and vitality and on the causes of tree mortality. Insect infestation, windthrow, drought and harmful organisms such as fungi, viruses and bacteria were seen to be primarily responsible for the mortality of trees still living at the time of NFI4 (2009–17). A frequent trigger for insect damage, especially that of bark beetle, was often pronounced periods of drought. Dry conditions had a particularly big impact in the Jura. Mortality varies depending on the region and tree species, which means that changes in the species composition are already becoming apparent, a finding borne out by the results of NFI5 on salvage logging.

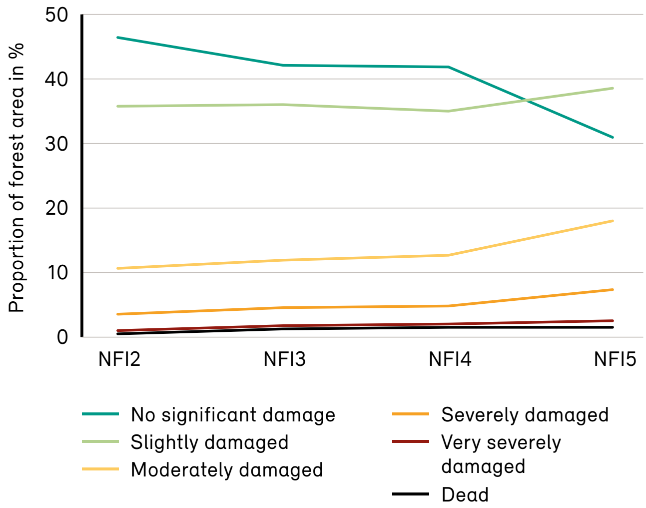
The forest areas affected by insect infestation and pathogens and those affected by windthrow and drought were similar in size throughout Switzerland. Compared with the NFI2 surveys (1993–95), the number of damaged trees increased only in the most recent observation period (Fig. 2.5.1). This tallies with the findings of the crown condition surveys (section 2.3). These observations indicate heavy climate-related pressure on forests.

Principles for climate-adapted tree species selection

The Forests and Climate Change research programme has developed a set of principles for selecting tree species adapted to climate change. Key factors in the choice of species are the calculation of altitudinal vegetation belts in a future climate (Zischg et al. 2021) and the suitability of sites according to ecograms (Braun et al. 2023C). These principles for recommended site-adapted tree species were published in 2018 (Frehner et al. 2018) and incorporated into the Tree App *(www.tree-app.ch)*. Mixed broadleaved forests should be promoted by suitable measures and the genetic diversity of forests increased (section 4.6). Native tree species should be favoured, with introduced species chosen only in exceptional cases. An implementation project for the research programme is also creating test plantations with different tree species and provenances (Frei et al. 2018). The test plants come either from native stands or from stands in warmer and drier regions outside Switzerland. The plantations, numbering over 50, are located throughout Switzerland and will provide valuable information over the coming decades.

Figure 2.5.1

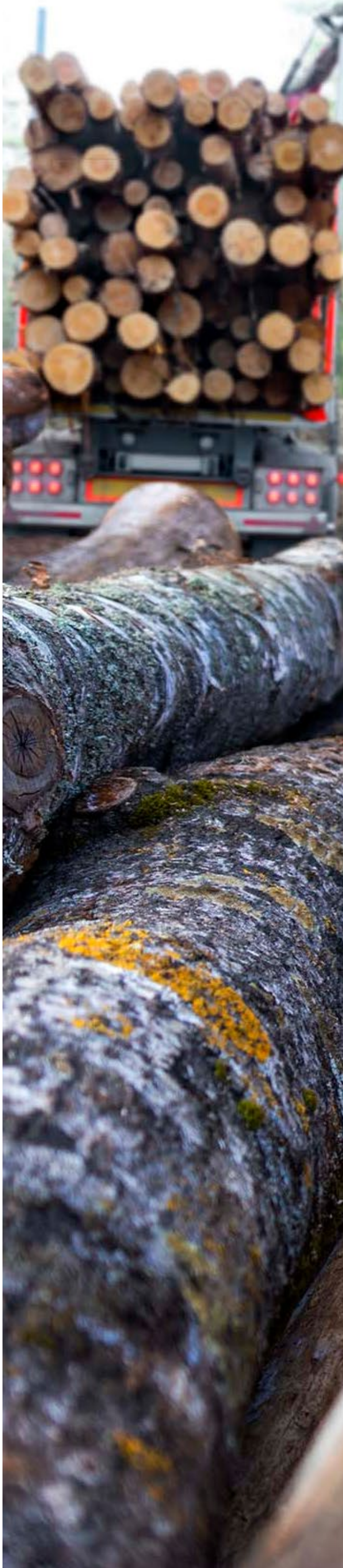
Development of the degree of damage in Swiss forest stands between NFI2 (1993–95), NFI3 (2004–06), NFI4 (2009–17) and NFI5 (2018–22). The degree of damage is based on an assessment of the damage to individual trees, extrapolated to the respective stand. The standard error for all values given is less than 1%.



Source: NFI (Abegg et al. 2023)

3

Harvesting



Harvested timber is sorted by species and stored in a temporary location in the forest.

Photo: Getty, Pink Badger

3 Harvesting

Janine Schweier, Alfred W. Kammerhofer

Wood is the most important raw material in forests for humans. Forests also provide other products and services whose sustainable use needs to be carefully planned in view of climate change. Since 2015, some 5 million cubic metres of wood have been harvested and sold annually, around 66% of it coniferous (softwood) and 34% broadleaved (hardwood). The net increment, which in simple terms represents the growth of living trees, is declining for the first time in some regions due to increasing mortality, especially in spruce and beech. The proportion of salvage logging has risen significantly, especially at lower altitudes. As climate change leads to more frequent dry periods, the proportion of softwood in the timber harvest is also expected to increase in the future. In addition to wood production, forests provide a variety of other supply, regulatory and cultural services. Providing these services incurs costs that have so far only been partially covered. Forest ecosystem services include non-wood forest products such as forest mushrooms, game meat, forest honey and Christmas trees. These are gaining in importance and can be converted ever more effectively into financial value. Climate change and society's growing demands on forests mean that forest planning is becoming more complex. It requires sound data collection and planning tools that are able to factor in all aspects of forest use.

3.1 Harvesting and increment

Marjo Kunnala, Christian Temperli

- Both gross and net increment in Swiss forests are declining in some regions.
- Mortality has risen sharply and accounts for 25% of the gross increment. There has also been a big increase in salvage logging following disturbances.
- Developments such as higher mortality and reduced increment are expected to continue, with regional differences. Disturbance management will therefore be an increasingly important factor in forest management.

Increment, harvesting and mortality

Increment, harvesting and mortality are important forestry parameters for assessing the productivity of forests and the sustainability of resource consumption (section 1.2). According to National Forest Inventory (NFI) terminology, the gross increment comprises the increase in volume of living trees, the volume of trees that have grown above the callipering threshold (12cm) and the modelled increase in the volume of trees harvested and of trees that died naturally but were not harvested (mortality). The net increment is the gross increment minus the volume of natural mortality. This contrasts with harvesting, which, according to the NFI, comprises the stem volume including stump and bark of all felled and removed trees, regardless of whether the wood is sold on the market, left in the forest or used privately. Harvesting and mortality together are also referred to as losses.

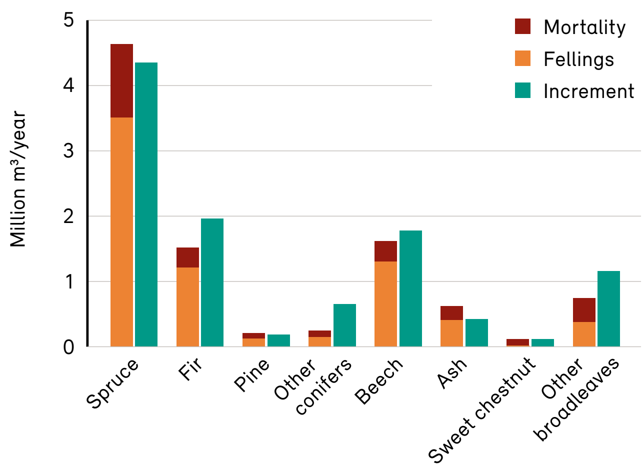
The gross increment in the period from NFI4 (2009–17) to NFI5 (2018–22) was 10.6 million cubic metres per year (million m^3/year) for the whole of Switzerland. This was 2.2% lower than between NFI3 (2004–06) and NFI4, when the gross increment stood at 10.8 million m^3/year. There was a particularly significant drop in the Jura (– 9.0%) and on the Plateau (– 7.3%) (Abegg et al. 2023).

The past decade has seen an increase in mortality, which rose from 1.7 million m^3/year to 2.6 million m^3/year and most recently accounted for 24.7% of the gross increment. Accordingly, the net increment across the country fell by 12.8%, from 9.1 million m^3/year to 8 million m^3/year. In the Jura, mortality more than doubled (+ 129.6%), meaning that this region saw the biggest drop in net increment (– 28.1%). An increase in mortality was also recorded in the Alps (+ 25.6%).

By contrast, harvesting decreased slightly nationwide, most recently standing at 7.1 million m^3/year. The ratio of harvesting and mortality to gross increment is an indicator for the trend in growing stock. If the value of harvesting plus mortality is more than 100% of the gross increment, the growing stock decreases. In the case of ash (148.0%), harvesting and mortality significantly exceeded gross increment in the past decade (Fig. 3.1.1), owing to the huge increase in mortality of this species as a result of ash dieback. The same applies to spruce (106.4%), pine (113.2%) and sweet chestnut (102.0%), the latter particularly widespread on the southern side of the Alps, although the ratios of these species must be interpreted with caution as the uncertainty ranges (standard errors) of harvesting/mortality and increment overlap. For beech, the ratio is 91.3%, almost the same as the figure for all tree species in Switzerland (91.4%), despite the sharp increase in mortality in the Jura. In the case of fir, harvesting and mortality equate to 77.1% of the gross increment.

Figure 3.1.1

Ratio of harvesting and mortality to gross increment (increment) in the inventory period from NFI4 (2009–13) to NFI5 (2018–22), by main tree species.



Source: NFI (Abegg et al. 2023)

These varying trends in gross increment, harvesting and mortality according to the production region depend on many factors, including disturbances such as winter storm Eleanor (Burglind) in January 2018 and locally extreme dry periods, as in 2018 and 2022 (Hermann et al. 2023). Insect and fungal infestations have also taken a heavy toll on forests (section 2.4, section 2.5).

Salvage logging

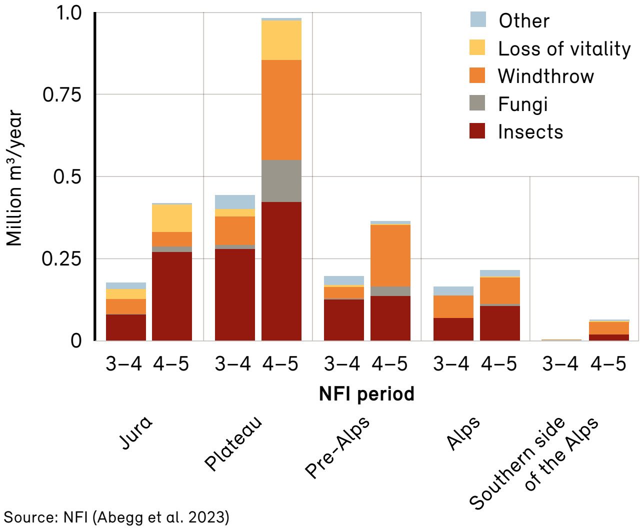
The proportion of salvage logging, i.e. unplanned harvesting that must be carried out following disturbances, has increased. Salvage logging is a time-consuming process during forestry work and results in higher costs and lower revenues for forest owners. In the period NFI3–NFI4, declared salvage logging averaged 1.1 million m^3/year, equivalent to 13.9% of total harvesting. In the period NFI4–NFI5, the quantity of salvage-logged wood nearly doubled to 2.0 million m^3/year, and most recently accounted for almost a third (29.0%) of harvesting. The proportion of salvage logging was highest on the Plateau and on the southern side of the Alps at around 35% each, and lowest in the Alps at 21.5%. The most common causes nationwide were insect infestation (46.6%) and windthrow (31.7%), followed by loss of vitality due to dry conditions/drought (9.3%) and fungal infestation (8.9%) (Fig. 3.1.2).

Sustainable forest development

The ratio of harvesting to net increment (excluding mortality) is an indicator of the sustainable use of wood as a resource. In the longer term, this ratio should be balanced. Regional increases in salvage logging and the decline in net increment saw harvesting rise slightly compared to net increment from 83.6% in the decade before last (NFI3–NFI4) to 88.6% in the past decade (NFI4–NFI5). Harvesting exceeded net increment in the Jura (124.2%) and on the Plateau (116.6%), resulting in a reduction in growing stock in these regions (section 1.2). However, harvesting is only one factor in assessing sustainability. Other forest ecosystem services such as protecting against natural hazards, filtering rainwater for use as drinking water, promoting biodiversity and providing habitat for plants and animals as well as recreational space for people, must also be taken into account. Appropriate silvicultural measures are required to guarantee the provision of these services. Depending on the objective, these may reduce the growing stock yet still increase the forest's overall sustainability, e.g. if a forest stand has been adapted to climate change.

Figure 3.1.2

Salvage logging in the surveys NFI3–NFI4 (2004–06 to 2009–17) and NFI4–NFI5 (2009–13 to 2018–22), by production region and main cause.



Source: NFI (Abegg et al. 2023)

The past decade has seen increased mortality and more salvage logging in some regions. Targeted silvicultural measures are therefore still required to shape the way in which forest develops and so maintain the forest ecosystem services demanded by the public. In climate-sensitive stands that are highly likely to be jeopardised by climate change in the future, adaptation measures might include increasing tree-species or structural diversity, shortening the rotation period, regeneration management or – failing all else – planting climate-compatible tree species (Pluess et al. 2016).

3.2 Round stack wood

Matthias Biolley

- Around 5 million cubic metres of wood (raw wood) are harvested in Swiss forests and temporarily stored on forest roads every year.
- The proportion of conifers (softwood) used for energy has risen significantly in response to increased demand.
- A further rise in wood harvesting is to be expected as a result of climate change. The increasing frequency of dry periods will see the share of softwood in total harvesting continue to grow.

Wood harvesting and use

This section reports on wood harvesting according to the Swiss Forestry Statistics. The data are based on a comprehensive survey of all forest enterprises and small forest owners. This records wood use by assortment and types of wood harvested and stored on forest roads, planting as well as the financial data of forest enterprises (excluding small forest owners). The data cannot be compared directly with the NFI sample surveys (section 3.1), as the two instruments measure different things in some cases and therefore allow different conclusions to be drawn (FOEN 2022c).

Between 2013 and 2021, an average of 4.8 million cubic metres of round stack wood was harvested from Swiss forests and marketed annually (FSO 2022a). Softwood (conifers) accounted for 66% and hardwood (broadleaves) for 34% of this total. Some 73% of the hardwood harvested was used for energy purposes, 14% was processed in sawmills and 13% was used as industrial wood, e.g. to produce particleboard. Of the softwood, 68% was processed as stemwood in sawmills, 22% was used for energy, and only 10% was used as industrial wood (FOEN 2022c, FSO 2022a).

Annual fluctuations in wood harvesting

The highest wood harvest in the past decade was 5.2 million cubic metres in 2018 (FSO 2022a). This was due to an above-average bark beetle infestation following the winter storms at the start of the year, coupled with very dry conditions during the summer and increased market demand. The lowest harvest was recorded in 2016, at 4.45 million cubic metres (FSO 2022a). Timber prices and market demand were lower that year, and salvage logging was minimal.

The proportion of softwood in the total wood harvest rose sharply in 2018 and has remained high since (FSO 2022a; Fig. 3.2.1). The rise reflects an increase in the harvest of damaged timber, especially softwood, as spruce, the most common coniferous species, is susceptible to windthrow and drought, particularly at lower altitudes.

The share of energy wood in the total timber harvest has risen continuously, with the increase again particularly pronounced in coniferous wood. In 2013, 18% of the softwood harvest was used for energy (FSO 2022a). By 2021, this had risen to 24%. The main reason for this was the increased demand for renewable energy and the associated expansion of wood energy plants, leading in turn to greater demand for energy wood.

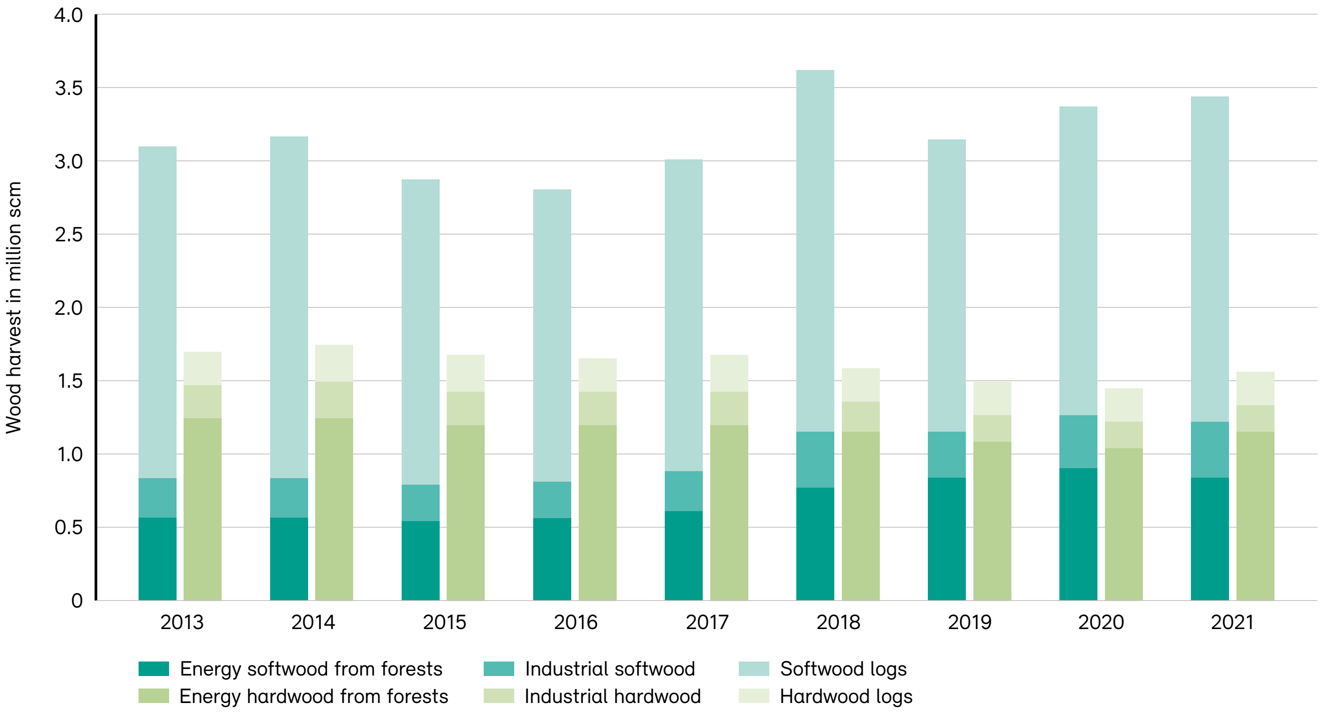
Developments in wood use

With extreme weather events set to occur more frequently in the future, salvage logging is expected to remain high, or even increase, over the next decade. This will result in more wood becoming available for processing and use. An increase in harvesting is also expected in forest management, as the strategies for adapting forests to climate change require continued, and potentially increased, harvesting to create more space for young trees (Brang et al. 2016). The trend towards a higher softwood harvest will continue because most climate-sensitive tree species, most notably spruce, are coniferous.

An increase in harvesting is also desirable from a political perspective (FOEN 2021b, FOEN 2021c). This is being promoted indirectly, e.g. by incentivising the use of wood, by reducing regulatory barriers and by co-financing cable crane systems and the adaptation or repair of forest roads (but not new construction, except in protective forests). Increased harvesting is part of the strategy for adapting to climate change and thus helps to maintain forest functions. However, it needs to be aligned with other adaptation strategy instruments such as biodiversity promotion. Finally, wood use also contributes to meeting climate-policy emissions targets. Political decisions therefore influence how and for what purpose wood will be used in the future. In view of the energy wood projects planned in many cantons, wood that was previously used in construction or furniture production, for example, could be burnt as fuel. However, this would contradict the cascade principle set out in the national Forest and Wood Strategy, which states that wood should be first be used as material, maximising its value, before being utilised for energy purposes (section 6.7).

Figure 3.2.1

Wood harvest by assortment and type of wood from 2013 to 2021.



Source: FSO 2022a

3.3 Non-wood forest products

Jean-Laurent Pfund

- Non-wood forest products have a high economic and social value for the population. Mushroom picking is steadily growing in popularity.
- Honey and chestnut production are being hit by the introduction of pathogens that harm bees and sweet chestnut trees.
- Except for hunting, few quantitative data are available. However, such data are key to enabling the inclusion of non-wood forest products in forest planning and ensuring that products such as mushrooms, chestnuts and forest honey are sustainably used and generate more value added.

Importance and special features of non-wood forest products

The Food and Agriculture Organization of the United Nations (FAO) defines non-wood forest products (NWFPs) as “goods of biological origin other than wood, derived from forests, other wooded land and trees outside forests” (FAO 1999). In Switzerland, game, wild mushrooms, forest honey, Christmas trees and chestnuts are among the most important NWFPs. Their social and economic value is generally underestimated. In fact, over 1.5 billion people globally use or trade such forest products (Shanley et al. 2016). In Europe, almost a quarter of households harvest NWFPs (Wolfslehner et al. 2019).

The NWFP economy is highly complex, encompassing a very diverse range of products in terms of both their origin (plant and animal species) and nature (meat, fruit, fibres, juice, roots). The quantities harvested, the time of availability and also the processing and marketing vary from product to product. In addition, forest owners have different rights of disposal depending on the product. In a bid to assess the market and development potential, an overview publication by the European Forest Institute classified NWFPs according to the personal contribution made by the consumers of these products – from mushrooms or berries that people pick themselves to industrially manufactured products such as cork, which are sold in supermarkets with virtually no personal input from consumers (Table 3.3.1; Wong and Wiersum 2019).

More than one in six people participating in the Socio-Cultural Forest Monitoring (WaMos) public survey reported picking NWFPs (FOEN 2022d; section 6.9). However, little research has been done into the details of these activities, such as harvesting locations, quantities and methods. While hunting processes are clearly regulated, access to forests and the gathering of fruit and berries for personal use are open to all by law. Management of some NWFPs such as mushrooms is supported by associations or interest groups.

Economic value and use

The total annual value of NWFPs in Switzerland is estimated at around CHF 80 to 90 million (Schmid 2015). Reliable data are only available for game, in the form of hunting statistics (FOEN 2023a). Just over 40,000 roe deer were shot each year between 2012 and 2021, while the number of red deer shot rose to 13,000. By contrast, fox and chamois hunting declined. The number of wild boar hunted varies cyclically from year to year, with between 8,000 and 12,000 animals shot. Revenue from the sale of game meat – from approximately 70,000 roe and red deer, chamois and wild boar – totals around CHF 20 million per year (JagdSchweiz 2017).

Mushroom picking is growing in popularity. Estimates for 2010 suggest that just under 250 tonnes of boletes, chanterelles and morels were collected (Limacher and Walker 2012).

Honey production varies annually depending on winter losses due to the reduced activity of honey bees in the cold season. It ranged from around 2,000 to 4,000 tonnes per year between 2005 and 2015 (Charrière et al. 2018). According to estimates, approximately 260 tonnes of chestnuts worth CHF 0.5 million are also harvested annually (Limacher and Walker 2012). The same study assumes that nearly 1.2 million Christmas trees are used in Switzerland each year. Around 10% of these, worth CHF 3.6 million, are harvested in Swiss forests. The value of imported Christmas trees and fir branches totalled about CHF 7.7 million in 2018, with a slight decline in consumption per household in recent years (Lehnmann 2019).

Table 3.3.1

Examples of non-wood forest products (NWFPs), classified according to the personal involvement of consumers in the product's value chain (green = high involvement; blue = medium involvement; grey = no involvement).

Involvement	Examples	Type of commodity and use	Characteristics
High involvement	Berries and mushrooms for use at home	Personal consumption	Personal collection and use of NWFPs within household
	Wild berry jam	Gifts	Personal collection and processing of NWFPs to be given as gifts to family and friends
Medium involvement	Leisure courses in the forest or involving NWFPs (e.g. basket weaving, recognising animal tracks)	Experiential products	Purchase and use of NWFP-based services and leisure activities
	Traditionally produced and locally marketed delicacies made from NWFPs (e.g. traditional mushroom pâté, liqueurs, forest honey)	Territorial products	Regional specialities only available in local markets, with local or supra-local marketing
No involvement	Birch sap for therapeutic purposes, boar bristles for natural bristle brushes	Niche products	Products aimed at a specialised market segment but marketed and distributed via standard channels (internet) without a local connection
	Cork for cork factories	Mass market/industrial raw materials	Sale of bulk raw materials for commercial use

Source: Wong and Wiersum 2019

Ecological threats

Fungal species diversity in Switzerland is high, with 10,000 recorded species (section 4.1). Mushroom picking does not appear to adversely affect this diversity (Egli et al. 2006). However, fungi are sensitive to soil compaction and pollution as well as to habitat decline and fragmentation (Senn-Irlet et al. 2007). Honey bees and sweet chestnut trees are threatened by non-native pathogens. For example, the *Varroa destructor* mite introduced from Asia is causing serious problems for beekeepers. The danger posed by pesticide residues is a further threat to the honey industry, while another arrival from Asia, the chestnut gall wasp, has negatively impacted chestnut production since 2009.

Prospects for sustainable use

Mushrooms offer an example of how NWFPs could potentially develop in the future, whether it be more intensive production or even domestication of forest products. In the neighbouring Italian region of Piedmont, silvicultural interventions to promote mushroom growth are already being trialled (Taglioferro et al. 2013). In Switzerland, however, forest owners do not have a right of disposal over the wild mushrooms growing in their forests, and cannot prevent the public from harvesting them, even if they make investments to boost mushroom growth. A next step could therefore be the non-forest production of NWFPs. Almost 7,000 tonnes of champignon mushrooms were produced in Switzerland from January to October 2021, around 13% more than in the same period in 2017 to 2020 (Kuhlgatz and Bolliger 2021).

More attention needs to be paid to NWFPs and their management in forest planning given the part they play in the forest ecosystem and forest functions. Also, more data must be collected on NWFPs in Swiss forests, to help ensure their sustainable harvest.

3.4 Forest ecosystem services

Oliver Wolf, Christian Temperli

- Forests provide a variety of services that enhance the public's safety and well-being. They provide protective, economic and welfare functions.
- The provision of forest ecosystem services incurs costs that have until now only been partially covered. These services can be valorised and monetised using indicators and expert-based valuation systems.
- Demand for forest ecosystem services will continue to rise as forests are increasingly used for recreational activity. This is likely to result in conflicts in the provision of different forest ecosystem services.

Importance of forest ecosystem services

Swiss forests provide a wide range of services. They produce biomass, protect against natural hazards, remove carbon dioxide from the atmosphere and provide a space for recreation. Forest ecosystem services are therefore essential not only for the forestry and wood industries but also for the safety and well-being of the public. The concept of forest ecosystem services, which is still under development, was originally based on that of 'ecological functions'; the diverse services provided by a habitat are brought together in the term 'ecosystem services'. Forest ecosystem services help forests to fulfil their functions, established in the Federal Constitution as protective, economic and welfare functions (Art. 77 para. 1 Cst.). The diverse forest ecosystem services contribute to these functions in different ways (Table 3.4.1). The Forest Act fleshes out the constitutional requirement to maintain forest functions and is implemented through the Integrated Forest and Wood Strategy 2050, which holds the various stakeholders accountable for maintaining and improving forest ecosystem services.

Maintaining forest ecosystem services

Forest biodiversity and resilience – i.e. forests' ability to adapt to changes and go on fulfilling their functions despite stresses such as climate change – are essential if forests are to be able to provide their diverse services. This requires close-to-nature and sustainable forest management, for example in the form of climate-adaptive forest management (Glatthorn et al. 2023). This type of forest management may also include non-use, in other words not undertaking any silvicultural interventions.

Many forest ecosystem services are public goods. However, the measures that make them possible in the first place incur costs for forest owners that are not covered by timber revenues alone. The cost recovery rate for forest ecosystem services other than wood use is currently around 60% (Arnold et al. 2020). Only when forest ecosystem services have been valorised can the measures necessary for their provision be remunerated or – if financial resources are scarce – deliberately dispensed with. Valorisation means monetising and financing management measures for the provision of forest ecosystem services.

Quantification and valuation

The valorisation of forest ecosystem services is based on two factors: quantification and valuation of the service, and public and economic demand. A lack of data, uncertainties in valuation and unanswered questions regarding monetisation currently pose major challenges for the calculation of forest ecosystem services. Indicators and expert-based valuation systems are used for quantification and valuation. The indicators link measurable variables such as forest structure with the corresponding forest ecosystem services, e.g. recreation (Bernasconi et al. 2022). Indicator and valuation systems are used in combination with forest development models to analyse management scenarios. They can also highlight the conflicting priorities of providing forest ecosystem services on the one hand and developing strategies for coping with climate change on the other (Thrippleton et al. 2021). Recording and documenting forest ecosystem services means that they can be clearly communicated and incorporated into policy-making processes.

Synergies and conflicting priorities

Global challenges such as climate change, biodiversity loss, and the transition to a sustainable economy and energy supply will further push up demand for forest ecosystem services (Ohmura et al. 2023). Forest ecosystem services such as carbon sequestration and the conservation of old-growth patches can be mutually beneficial, while others such as wood production and the possible need to abandon silvicultural interventions may be in competition (Blattert et al. 2020). There is a further potential conflict between forest ecosystem services and efforts to make forests less susceptible to disturbance. For example, measures such as shorter rotation periods or more frequent interventions in a forest stand, which reduce susceptibility to damaging events, may conflict with biodiversity-promoting measures such as leaving old-growth patches standing (Temperli et al. 2020). To reduce such conflicts, the various factors and their interactions must be carefully weighed up. Only by including all forest ecosystem services in forest planning in line with integrated forest management can synergies be leveraged and services duly remunerated, thus ensuring that they can be provided in the long term.

Table 3.4.1

Forest functions and associated forest ecosystem services. (Z = ecosystem service classes according to the Common International Classification of Ecosystem Services: P = provisioning services, R = regulating services, C = cultural services).

Forest functions	Forest ecosystem services	Z	Sections in FR 2025
Economic function	Production of material biomass (stemwood, industrial wood)	P	1.2, 3.2, 6.7
	Production of energy biomass (energy wood)	P	3.2, 6.7
	Production of non-wood forest products (e.g. berries, mushrooms, medicinal plants or game meat)	P	3.3
Protective function	Protection of people and significant physical assets from gravitational natural hazards (landslides, rockfall, avalanches, entry of debris and driftwood into watercourses)	R	5.1
Welfare function: Recreation and health	Space for recreation, relaxation, and sensory stimulation and development	C	6.9
	Space for sport and adventure	C	6.9
	Space and inspiration for culture and art; cultural heritage (e.g. monuments, rare forms of forest management)	C	6.10
	Space and inspiration for spirituality and religion; forest burials	C	6.10
	Regulation of climate and microclimate; absorption of air pollutants (e.g. particulate matter), oxygen production	R	2.1
	Landscape shaping and aesthetic experiences	C	4.7
	Drinking water supply, water filtration	P	5.2
	Reduction of nuisances (e.g. noise)	R	
Welfare function: Habitat for animals and plants	Provision of nature value and habitat services	R	4.1, 4.9
	Habitat for native species as a basis for pest control and pollination	R	4.1, 4.8, 4.9
	Maintenance of nutrient cycles, regulation of life cycles	R	
Welfare function: Other tasks	Hydrological regulation, water storage and retention	R	5.2
	Carbon sequestration and storage in forests and carbon storage in wood	R	1.4
	Provision of genetic resources (e.g. seed production, forest propagation material)	P	4.6
	Soil formation and stabilisation	R	2.2
	Provision of minerals and other abiotic products	P	2.2
	Bioremediation by microorganisms; physical degradation of pollutants	R	
	Subject for education, research and citizen science; experiential space for environmental education	C	6.11

Source: FOEN 2022e

3.5 Forest planning, certifications and trade regulations to protect against deforestation

Roberto Bolgè, Leo G. Bont, Olivier Schneider, Matthias Biolley

- Forest planning is becoming ever more important in Switzerland because of the growing demands on forests and the effects of climate change.
- Advances in digitalisation, remote sensing and mathematically-based decision-making systems are enhancing the basis for long-term planning of sustainable, economic and ecological forest management.
- The global threat to forests from deforestation, particularly in agricultural production areas, and from illegal logging is leading to stricter legal regulations on the trade in raw materials and products associated with deforestation in the EU, the US, Australia, Japan and also in Switzerland.

Legal basis for forest planning

The responsibilities for forest planning are enshrined in the Forest Act (Art. 20 para. 2 ForA) and fleshed out and implemented at cantonal level. The current system was introduced following a complete revision of the Forest Act in the early 1990s. This provides for two planning levels: the authorities, which coordinate the forest functions in forest development plans (FDPs), and the forest owners, who organise forest management in forest enterprise management plans (Bachmann 2005). This two-tier system has so far proved effective. Additional planning instruments have been introduced to address the challenges facing the forestry and wood industries. For example, the cantons have developed their own forest strategies or forest mission statements in addition to the FDPs, as described in an evaluation report on optimising forest policy (Lieberherr et al. 2023).

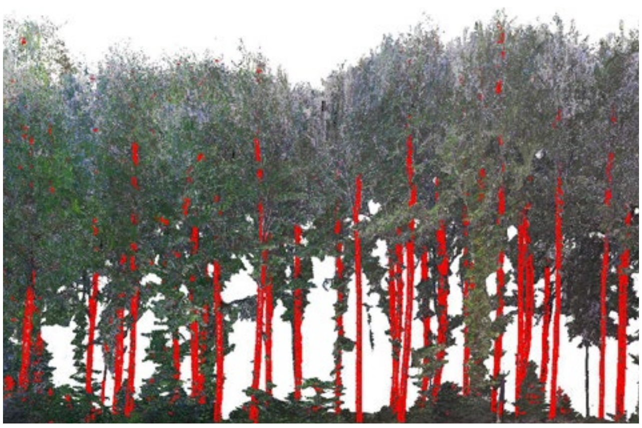
Recently there has been a greater focus on coordinating forest planning and spatial planning. Officially, this coordination is clearly defined, given the separation of responsibilities laid down in the Forest Act and the Spatial Planning Act. In practice, however, there are conflicts of interest, especially between forest conservation and land use (section 1.1). Forest use and other forms of land use must therefore be well coordinated in the interests of forest conservation and ecological connectivity.

Data collection and digitalisation

Advances in data collection and processing are shaping modern forest planning. Remote sensing data and digitalisation provide the required planning information on forest condition and development faster and in better quality than was previously possible. As forest planning becomes increasingly complex, having to factor in a wide range of forest ecosystem services and the challenges of climate change, the quality and analysis of the data collected are becoming ever more important (section 3.5.1). Future research will therefore focus on data analysis, e.g. using modern two-phase inventories or automatically derived stand maps, and on the integration and valuation of ecosystem services. Sophisticated visualisations (virtual forest) and decision support systems with mathematical optimisation, which model forest development under various climate and management scenarios, will support long-term forest planning in the future.

Figure 3.5.1

Automated forest inventory in the Ramerenwald near Birmensdorf (ZH) using a Leica BLK360 stationary terrestrial laser scanner. The data points of the point cloud recorded by the scanner have been coloured with the RGB (red-green-blue) information from the integrated camera. The automatically detected tree stems are highlighted in red.



Source: Daniel Kükenbrink (WSL)

Certificates and labels

Illegal logging is pretty much a non-issue in Swiss forests. However, that is not the case in many countries around the world, where this problem has many negative consequences for ecosystems, societies and economies. A number of measures have been taken at international and national level to curb the trade in illegally harvested timber, including the voluntary certification of forests and wood. This certification indicates that forest management is environmentally and socially responsible, as well as economically viable. With more and more environmentally conscious consumers looking for wood products that are labelled, many wood product suppliers, including here in Switzerland, rely on certification to attract such customers.

Two systems of certification are used in Switzerland: FSC (Forest Stewardship Council) and PEFC (Programme for the Endorsement of Forest Certification). They are based on national standards and have different requirements for silvicultural practice, monitoring material cycles and the organisation of forest enterprises. Internationally, 192 million hectares of forest carried the FSC label and 290 million hectares the PEFC label in 2022, equivalent to 5% and 7% respectively of the global forest area. In Switzerland, the first forest areas were FSC-certified in 1998. By 2022, 26% of the total 1.31 million hectares of forest was FSC-certified (FSC 2023), while 18% was certified by both FSC and PEFC (PEFC 2023). The highest level to date was in 2013, when 54% of the area was certified. Since then, the proportion of certified forest area has fallen by around 10%, in part because some forest owners have stopped renewing their certification because of the costs and the lack of economic added value of the certificates. In the 24 cantons (accounting for 87% of Swiss forest area) that report the proportion of certified areas, 65% of public forests are certified, compared with just 16% of private forests.

Wood-processing companies in Switzerland can also be certified with the 'Swiss Wood' (Schweizer Holz) label, provided that their products consist of at least 80% Swiss wood. Switzerland's entire forest area is 'Swiss Wood'-certified.

Legal regulation of trade to protect against deforestation

The new Timber Trade Ordinance (TTO; SR 814.021) came into force in 2022. It prohibits the placing on the market of illegally harvested or traded timber. The TTO thus implements, and is considered an equivalent regulation to, the European Union Timber Regulation (EUTR, 955/2010), which has been in force since 2013. Both aim to exclude illegal timber from the European market, and primarily affect traders and forest owners. Companies must exercise particular care when placing timber or wood products on the market for the first time. They must demonstrate that the risks of illegal timber finding its way onto the market can be reduced to a negligible level and must set up a due diligence system that is regularly updated. Certifications may cover part of the due diligence obligations. The TTO applies to both domestic products and imported goods.

A duty to declare with respect to timber and wood products has been in force in Switzerland since 2010 (SR 944.021). It primarily affects companies that sell wood products directly to consumers. The wood declaration must specify the type and origin of raw wood, semi-finished products and finished products that consist of solid wood or a significant proportion of solid wood. The duty to declare applies to both domestic products and imported goods.

From 2025, the European Deforestation Regulation (EUDR, 2023/1115; Deforestation-Free Supply Chain Regulation) will apply in the EU. This makes raw materials and products that could be linked to deforestation subject to due diligence; these include soya, palm oil, beef, coffee, cocoa, rubber and wood, especially products from tropical regions. These products may only be placed on the market if proof is provided that they were not produced on land deforested after December 2020.

4

Biodiversity

Wetlands are particularly valuable forest habitats for species diversity. However, they are under considerable threat in some regions.

Photo: FOEN

4 Biodiversity

Martina Peter, Timothy Thrippleton, Claudio de Sassi

The past decade has seen a slight improvement in forest biodiversity. Both the state and the development of biodiversity are generally better in forests than on open land. The diversity of gastropod (snail and slug), moss and tree species and the populations of most forest bird species have increased, while the situation of endangered forest species is stable to slightly improved. This progress is due to the positive development of the overall ecosystem. Unnatural stands have decreased, while structural diversity and deadwood volume have increased. Forest reserves are approaching the target of 10% of forest area. Nevertheless, regional differences and deficiencies remain. On the Plateau, for example, 70% of stands have an unnatural proportion of spruce and are susceptible to disturbances. Meanwhile, 41% of forest communities – and thus the habitats of numerous species – are endangered. A high level of genetic diversity in trees would offer potential for adapting forests to climate change and should be taken into account in silvicultural strategies. The opportunities and risks of cultivating non-native tree species and of increased use of energy wood must be carefully weighed up with regard to the consequences for biodiversity. Biodiversity is the basis of forest resilience and is therefore essential for maintaining forest functions. However, climate change poses a challenge for maintaining biodiversity. Connecting forests in the landscape to allow species communities to adapt more easily to climate change is becoming increasingly important.

4.1 Species diversity

Kurt Bollmann, Silvia Stofer, Meinrad Abegg, Timothy Thrippleton

- The species composition in Swiss forests is changing. While ash and sweet chestnut have declined, there have been increases in maple and Arolla pine and in the average number of moss and gastropod species.
- Around 40% of Switzerland's animal and plant species live in forests, with the proportion of forest-dwelling species particularly high among lichens, macrofungi, bats and longhorn beetles.
- The decline of ash trees will adversely affect the communities associated with them, such as lichens, mosses and fungi. In addition, climate change, invasive neophytes and atmospheric nitrogen deposition are set to further alter the species composition in forests.

Development of tree species in Swiss forests
With its diverse topography and large differences in altitude, Switzerland boasts a wide range of site conditions, which is reflected in a rich variety of flora, including in its forests. Around 700 vascular plants are considered typical forest species, including 39 native broadleaved and seven coniferous species (Rudow 2014). Three tree species predominate in Swiss forests, together accounting for around two thirds of all trees: spruce (36%), beech (18%) and fir (11%). However, tree species composition varies considerably with altitude and region. On the southern side of the Alps, for example, sweet chestnut is also very common, accounting for 15% of the total.

There are various reasons for the changing composition of forest stands in Switzerland: natural succession, changing climatic conditions, harmful organisms, disturbance events and forest management. In the survey of stem numbers, maple increased by 1.4% per year and Arolla pine by 1.1% per year between the fourth and fifth National Forest Inventory (NFI4 2009–17 to NFI5 2018–22), while spruce decreased by 0.5% per year during this period (Fig. 4.1.1; Abegg et al. 2023). Because spruce is by far the most common tree species in Switzerland, its decline contributes most to the change. The sweet chestnut saw the sharpest drop in the number of stems. Despite this, its growing stock hardly changed because it was mainly thinner trees that died, while the number of large trees remained stable and these trees increased in volume. A similar effect was seen to a lesser extent in beech and oak, which declined by 0.4% and 0.8% per year respectively. Scots pine declined significantly almost everywhere, with a particularly sharp drop of 4% per year in both the western Plateau and northeastern Alps.

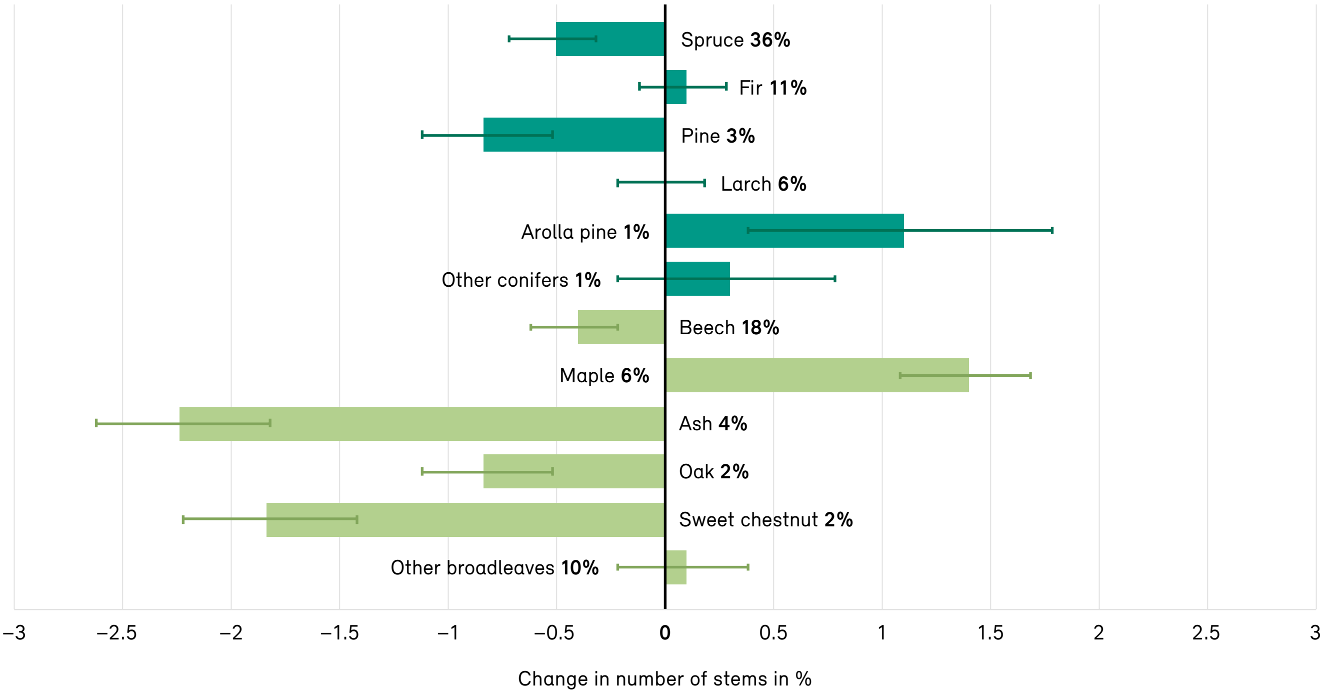
Across the country, ash recorded the largest annual decline of 2.2%. It was affected by ash dieback, a disease caused by the parasitic fungus *Hymenoscyphus fraxineus* introduced from East Asia. By way of exception, the region on the southern side of the Alps saw a slight increase in ash.

The decline of the ash has consequences for forestry but also for species diversity as it provides a habitat for many gastropod and insect species, and in particular for flowerless organisms (cryptogams) such as mosses, lichens and fungi. In Switzerland, for example, around 150 moss species, over 450 tree-dwelling lichen species and some 850 saprophytic or parasitising fungi species have been recorded on ash trees (Swissbryophytes; SwissLichens; SwissFungi). The ash is distinctive among native broadleaved trees for it its pH-neutral bark. This makes it a favoured habitat for tree-dwelling lichens in particular. The effects of the large-scale loss of ash trees on the development of these species are still hard to assess. It is important to conserve and encourage the growth of healthy or less affected ash trees to ensure that any resistance to the ash dieback pathogen is passed on to future generations of trees (Rigling et al. 2016). Research has found that ash trees that are resistant to ash dieback also have increased resistance to the introduced emerald ash borer beetle *(Agrilus planipennis)* (Gossner et al. 2023).

Tree species composition in stands
In view of climate change, a diverse mix of tree species – as well as a generally high species diversity – is advantageous as this spreads the risk of stress intolerance across multiple species (Brändli and Bollmann 2015). In the tree layer, little has changed in the past decade. The proportion

Figure 4.1.1

Gains and losses in the number of stems of living trees with a diameter at breast height of 12cm or more by main tree species between NFI4 (2009–17) and NFI5 (2018–22). The percentages refer to the proportion of stem numbers nationwide.



Source: NFI (Abegg et al. 2023)

of stands with only one tree species has fallen slightly to 17% of the forest area. This figure is well below the European average of 33% (Forest Europe 2020). For woody species over 40cm in height, the positive trend seen in the previous period has continued, with the number of species increasing to an average of 6.7 per 200 square metres. The same trend can be observed on forest edges. As a transition zone between different habitats, these play an important role in species diversity. According to NFI estimates, their total length in Switzerland is around 115,000 kilometres (Brändli et al. 2020). Species-poor forest edges with a maximum of five woody species observed per 50 metres have fallen to a share of 4.5% of the total forest edge, while species-rich stands with 16 or more species per 50 metres of forest edge have increased to 34.1%.

From 2008 to 2020, targeted measures to promote biodiversity through forest edge management and habitat enhancement as well as to support historically and culturally significant forms of management such as wooded pastures and nut orchards were implemented on a total area of more than 25,000 hectares under programme agreements between the Confederation and cantons (Stadler and de Sassi 2021). Measures aimed at conserving these forms of management and their special biodiversity are essential. They have a demonstrably positive impact on local biodiversity (Bühler and Roth 2021). The positive development of biodiversity across the entire forest area is primarily due to the favourable development of the overall ecosystem. Close-to-nature forest management plays a key role in this.

Diversity of other species groups

Forests boast a disproportionately high number of species in relation to their area. Of the approximately 56,000 species recorded in Switzerland, around 40% live in or depend on forests. However, the proportion of forest species differs depending on the organism group. In the case of bats, longhorn beetles, macrofungi and lichens, the proportion is above average, at over 80% (Brändli and Bollmann 2015), whereas the figure for native vascular plants is much lower, at less than 25%. Of the roughly

6,000 macrofungi catalogued in Switzerland, 3,650 are classed as forest species. Species that regularly occur in or along the edge of forests include 428 mosses, 130 gastropods and 27 butterflies and moths. Although the proportion of endangered breeding bird species in forests is significantly lower than the national average at nine out of 59 species, there are forest bird species whose populations are declining, such as woodcock, turtle dove, grey-headed woodpecker, tree pipit, wood warbler and citril finch (Knaus et al. 2021; section 4.10).

Development of selected groups of organisms

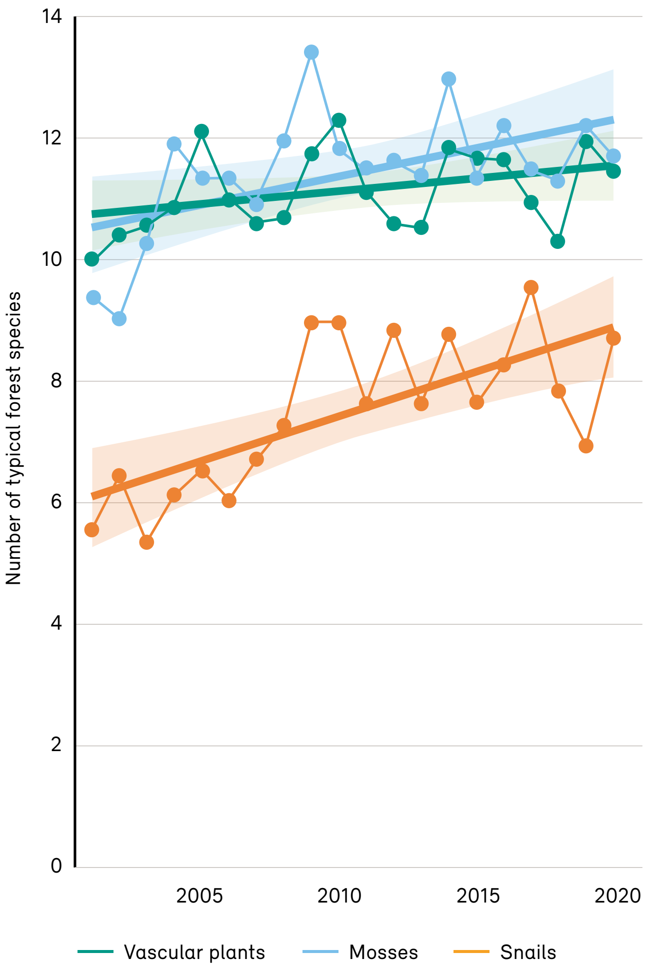
Between 2000 and 2020, Swiss Biodiversity Monitoring (BDM) found a continuous increase in the species diversity of forest snails and forest mosses in the forest areas analysed (FOEN 2014; Fig. 4.1.2). In the case of forest snails, both the number of species and the number of individuals had risen. The increase in the number of individuals is directly related to the increase in the supply of deadwood (section 4.5). The species diversity of forest mosses increased on BDM monitoring plots where the stands had become denser and shadier. In addition to structural changes, the growing availability of nutrients combined with reduced sulphur dioxide pollution is also likely to have had a positive effect on forest moss diversity (Birrer et al. 2022).

By contrast, the species diversity of vascular plants as a whole had not changed significantly (Fig. 4.1.2). While fewer forest plants were observed on BDM plots with higher tree stand density, the decline in the proportion of conifers in the vegetation belts where broadleaved forests are typically found (colline and montane) led to an increase in the species diversity of vascular plants (Birrer et al. 2022).

For species with special habitat requirements in terms of light, water, nutrients and deadwood, BDM cannot be used to identify trends for methodological reasons. This would require additional investigations. The situation of wood ants, for example, was surveyed as part of NFI4 (Wermelinger et al. 2019). Among other things, these favour open groups of trees, rather than a closed canopy, and forests with a high proportion of conifers. Wood ant mounds were found on one in 20 NFI sample plots. Nine out of ten ant mounds occurred in the natural distribution area of coniferous forests. Wood ants were twice as

Figure 4.1.2

Development of the species diversity of forest plants, forest snails and forest mosses on 564 10m² BDM monitoring plots. The straight lines show the trend with a 95% confidence interval.



Source: Birrer et al. 2022

common in natural forest reserves as in special forest reserves (Brändli et al. 2020), because the natural forest reserves tend to be situated at higher altitudes than the special forest reserves and natural coniferous forests are more common at higher altitudes than at lower ones (section 4.9).

Game population

Wild ungulates are faring well in Switzerland. The roe deer is widespread from lower altitudes to above the upper forest boundary. Its population was estimated at around 135,000 in 2021 (FOEN 2023a). Red deer have increased by 27% in the past decade to around 39,000, and have spread further in the central and western Pre-Alps, with some now penetrating onto the Plateau. The chamois population has remained stable at 91,000. No reliable estimates are available for the wild boar, but it is likely to benefit from climate change and expand its range into the Pre-Alps. Large carnivores such as wolves and lynx are benefiting from the high ungulate populations. The lynx has established itself in the Jura and the western and central Alps and is advancing into the eastern central Alps. The wolf population has also increased considerably; in 2023, there were around 240 individuals living in 23 packs, mainly in the Alps and western Jura (KORA 2023). A few have now also been spotted on the Plateau. Both wild ungulate and large carnivore populations are likely to continue growing in some regions over the next decade.

Impacts of climate change

Overall, the trend in the species diversity of trees and many other forest species is positive. However, the example of the ash shows that many species are directly or indirectly dependent on each other. The complex interactions within the forest ecosystem are susceptible to the effects of climate change (section 2.5), the spread of invasive neophytes (section 4.4) and excessive nitrogen deposition from the atmosphere (section 2.1). Thus, climate change may lead not only to range shifts of species to higher altitudes, but also to altered interactions between species groups, e.g. between flowering plants and insects. These impacts may pose a particular risk to specialist species that rely on rare habitats or on other species (section 4.8).

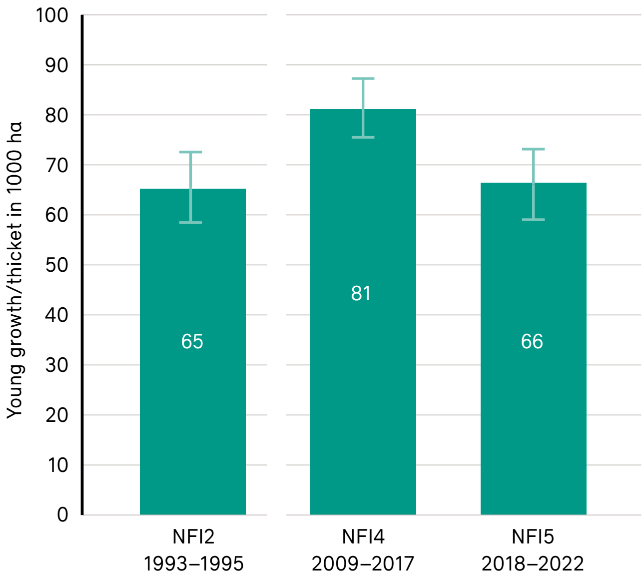
4.2 Regeneration

Barbara Moser, Meinrad Abegg, Andrea D. Kupferschmid, Petia Nikolova, Daniel Scherrer, Timothy Thrippleton, Robert Jenni

- The density of young trees has decreased in the past decade as the regeneration areas created by storms Vivian and Lothar have grown over again. Ungulate browsing is also influencing the species composition in many regions and reducing the regeneration density. Both young-growth and adult populations of ash north of the Alps and of sweet chestnut in Ticino have declined.
- Natural regeneration is the dominant form of regeneration in Swiss forests, accounting for 90.9% of the total regeneration area. This reflects the economic and ecological advantages of natural regeneration in close-to-nature forest management.
- Species-rich tree regeneration is necessary to ensure forest's resilience to disturbances and its ability to adapt to climate change.

Figure 4.2.1

Total area of stands in the young growth/thicket stage of development in NFI2, NFI4 and NFI5.



Source: NFI

Development of regeneration areas

Regeneration enables forests to adapt to changing environmental conditions. In close-to-nature forest management, natural regeneration has priority. Compared with artificial regeneration through planting, it offers the ecological advantage of greater genetic and structural diversity and the economic advantage that no seed collection costs are incurred. The share of natural regeneration in the total regeneration area increased slightly to 90.9% between the fourth and fifth NFI (NFI4 2009–17 to NFI5 2018–22).

Young trees can establish themselves in the forest if the environmental conditions are favourable for seed germination and growth. This is mainly the case in clearings, where the plants have sufficient light for growth. Storms Vivian in 1990 and Lothar in 1999 created many temporary open spaces, which led to an increase in regeneration areas, particularly on the Plateau, in the Pre-Alps and in the Alps (section 4.2.1). Succession has now made further progress on these sites, resulting in another reduction in open areas. Accordingly, the density of young beech and spruce has fallen back to 1995 levels (NFI2 1993–95) in the past decade. The density of young oaks has remained constant, while that of young European silver firs has continued to increase since NFI4 in the Jura (+ 20%), on the Plateau (+ 22%) and in the Pre-Alps (+ 56%). The density of young ash trees has declined in the Jura (– 18%), on the Plateau (– 46%) and in the Pre-Alps (– 43%), while remaining stable in the Alps and on the southern side of the Alps. The decline is likely to be a consequence of ash dieback (Dubach et al. 2023; section 2.4). The regeneration values for sweet chestnut in Ticino have fallen continuously since 1995, but to a lesser extent after 2015 than before.

Diversity of regeneration and inhibiting factors

Diverse regeneration – diverse in terms of species composition as well as genetic and structural diversity – promotes adaptability to climate change (Pluess et al. 2016). Abundant regeneration of Norway maple and oak is desirable at low altitudes, that of sycamore and European silver fir at medium altitudes. This is because these trees are regarded as future-adapted species, meaning they are likely to become more important given the expected changes in site conditions. To ensure a climate-adapted forest, these species should gradually replace pure beech stands or site-inappropriate spruce cultures (Temperli et al. 2023). A number of native tree species that are still rare today, such as the true service-tree, the wild service-tree and the Italian maple, should also be promoted because they are of particular value for climate change adaptation and forest biodiversity.

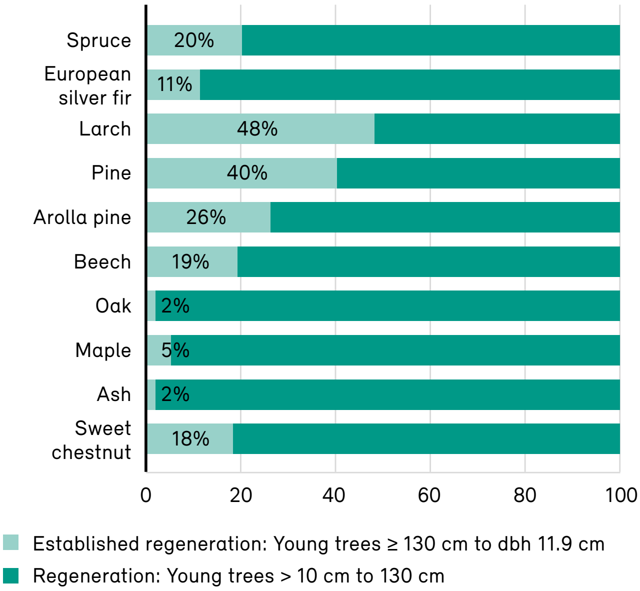
Until young trees reach the tree layer, they are exposed to a variety of inhibiting factors such as frost, heat, drought and shade. They are also affected by vegetation competition, pathogens and ungulate browsing. The high mortality of young trees is caused by various natural factors, including lack of light when regeneration areas become overgrown. Browsing by wild ungulates also impedes natural regeneration in many regions (Imesch et al. 2015). Tree species composition is affected when game populations are out of balance with their habitat capacity or disturbances have an unfavourable effect on their spatial distribution.

Established regeneration

On the NFI sample plots, trees are recorded as young trees if they are taller than 10cm and have a diameter of less than 12cm at a breast height of 1.3m (dbh < 12cm). The taller trees grow, the more robust they are. Young trees over 1.3m tall are considered as 'established regeneration', as they have established themselves against the competing vegetation. Also, their main shoot can no longer be reached by game (Ott et al. 1991). The proportion of established regeneration in relation to the total number of young trees is an important measure of successful long-term forest regeneration. In the case of pioneer tree species that require light, such as larches and pines, the proportion of established regeneration is naturally high at 48% and 40% respectively (Fig. 4.2.2), as their seedlings exhibit rapid height growth. Spruces and beeches, on the other hand, are exposed to inhibiting factors for longer due to their slower juvenile growth. For this reason, a smaller proportion of trees of these species (20% and 19% respectively) reach established regeneration. This proportion decreases if a species is regularly affected by disease, pests or ungulate browsing. A low proportion of established regeneration, especially in species such as oak and maple, could jeopardise the provision of desired ecosystem services and should therefore be closely monitored.

Figure 4.2.2

Established regeneration as a proportion of total regeneration by tree species, 2022. The greater the proportion of established regeneration, the more successful the forest regeneration.



Source: NFI (Abegg et al. 2023)

Investigations into vegetation dynamics following storms Vivian and Lothar have significantly improved our understanding of regeneration dynamics (Wohlgemuth and Kramer 2015). More data on regeneration are also now available. They suggest that, for some tree species, ungulate browsing could be mainly responsible for the low proportion of established regeneration observed. However, there are still not enough sufficiently robust data on established regeneration to define site- and species-specific target values for maintaining forest functions in the longer term.

4.3 Naturalness

Daniel Scherrer, Meinrad Abegg, Robert Jenni, Timothy Thrippleton

- Around 20% of forest areas have not been used for over 50 years. Most of these are in the Alps, where they account for 46% of the forest area, followed by the Pre-Alps (36%). On the Plateau, conversely, 97% of forests have been used in the past 50 years.
- Unnatural stands have continued to decline. Nevertheless, forests in late stages of development, which are particularly valuable for species diversity, are lacking, especially at lower altitudes.
- On the Plateau, less than 30% of the forest area is close-to-nature. The high proportion of unnatural forests entails more risks, as these stands are more susceptible to disturbances caused by drought and harmful organisms, which will occur more frequently as climate change progresses.

Pristine forest and natural forest

A pristine forest is a forest in which earlier human use is not known or occurred so long ago that it no longer has any influence on the structure and composition of the forest. It differs from managed forest in terms of age composition and the prevalence of different tree species. It also features larger quantities of deadwood. As natural habitats, pristine forests are of irreplaceable value for many plant and animal species, especially species that are sensitive to disturbance and those that live in old or dead wood (section 4.5).

Across Europe, pristine forest accounts for 2.2% of the total forest area. It is mostly located in very remote areas with often extreme climatic or topographic conditions (Forest Europe 2020). Switzerland's two pristine forests, in Derborence (VS) and Scatlè (GR), cover only around 30 hectares, less than 0.01% of the country's total forest area (Brang et al. 2011).

A natural forest is a former cultivated forest that has developed from natural regeneration, has a close-to-nature tree species composition and has been able to develop over a long period without human intervention (Brang et al. 2011). It can go through all the phases of natural forest development and is 'on the way' to becoming pristine forest. In Switzerland, a total of 271,500 hectares, or 22.4% of the total forest area, has not been managed for at least 50 years, of which 101,400 hectares (8.4%) have not been used for over 100 years. The proportion unused for over 50 years has risen by 11.2% in the past decade, whereas the proportion unused for over 100 years has fallen by 3.7%. These forests are most widespread in the region on the southern side of the Alps and in Valais, but are very scarce in the Jura and on the Plateau. Designated natural forest reserves allow some forests in all parts of Switzerland to follow a natural dynamic and biodiversity to develop unhindered (section 4.9).

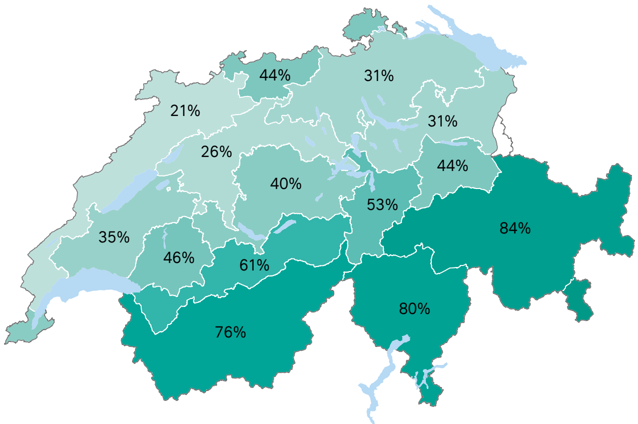
Criteria for forest naturalness

A forest's degree of naturalness indicates how closely its structure and composition correspond to a forest that has grown without anthropogenic influences. However, there is no officially recognised qualitative or quantitative basis for a general assessment of naturalness. The most frequently used criteria are site-appropriate tree species composition and structural diversity. The structural diversity criterion includes characteristics such as crown closure, stand density and the occurrence of internal forest edges, gaps, old timber and giants. Structural diversity in Swiss forests has been steadily increasing since NFI1 (1983–85). Today, 42% of forest areas have a high structural diversity.

A site-appropriate proportion of conifers is an important factor in assessing naturalness (Fig. 4.3.1). The area of forest with a close-to-nature proportion of conifers has risen to 51% of the total area across Switzerland (Abegg et al. 2023). Two thirds of these forest areas are located in mountainous regions, where coniferous forests are naturally more prevalent (coniferous forest area). They are therefore close-to-nature by definition. Conversely, at lower altitudes, where broadleaved trees naturally dominate (broadleaved forest area), a high and therefore less site-appropriate proportion of conifers indicates anthropogenic interventions and hence forests that are more unnatural. In the broadleaved forest area,

Figure 4.3.1

Proportion of forest area in Switzerland's 14 economic regions that is categorised as close-to-nature based on a site-appropriate proportion of conifers, 2022.



Source: NFI

especially on the Plateau, the proportion of moderately to very unnatural stands is still high, at 70%. Such stands are more susceptible to disturbances (Scherrer et al. 2022, Scherrer et al. 2023), especially under the combined effects of drought and windthrow, with subsequent bark beetle infestation. Thanks to the close-to-nature forest management with natural regeneration practised throughout Switzerland (section 4.2) and following regrowth after disturbance events, unnatural stands with a proportion of conifers of over 75% and very unnatural stands with a proportion of spruces of over 75% have declined from 26% to 21% since the NFI1 survey (1983–85).

The broadleaved forest area will continue to expand as the climate goes on warming, thereby reducing the natural proportion of conifers. In addition, species shifts within the broadleaved area are to be expected, with beech likely to lose ground to oak and other broadleaved tree species (Pluess et al. 2016). To take account of the species shifts in broadleaved areas and the naturalness of forests in coniferous areas, it is important to evaluate naturalness not only based on the proportion of conifers but also using more detailed indicators (Scherrer et al. 2023).

Biotope value and habitat diversity

The biotope value enables a holistic assessment of a forest's condition and development from an ecological perspective. It is calculated based on several criteria, including tree species diversity, structural diversity (crown closure, layering, stage of development) and forest naturalness, and is considered a measure of the habitat quality for animal and plant species. It has increased slightly in Swiss forests in the past decade. Around 55% of forest areas now have a high biotope value; these are found primarily in the mountain cantons of Valais, Ticino and Graubünden.

The ecological condition and species diversity of a forest depend to a large extent on the tree-species and structural diversity, the quantity of deadwood and the number of habitat trees (section 4.1, section 4.8). Close-to-nature forest management, the development of old-growth patches and the designation of forest reserves are key to promoting these structural elements. Switzerland has an exceptional diversity of forest habitats by European standards. Many are on the list of National Priority Habitats and are therefore considered particularly worthy of conservation (FOEN 2019a). The protection and promotion of these diverse and close-to-nature habitats plays a major role in biodiversity conservation throughout Switzerland.

4.4 Non-native tree species

Marco Conedera, Kathrin Streit, Meinrad Abegg, Robert Jenni, Bruno Lauper

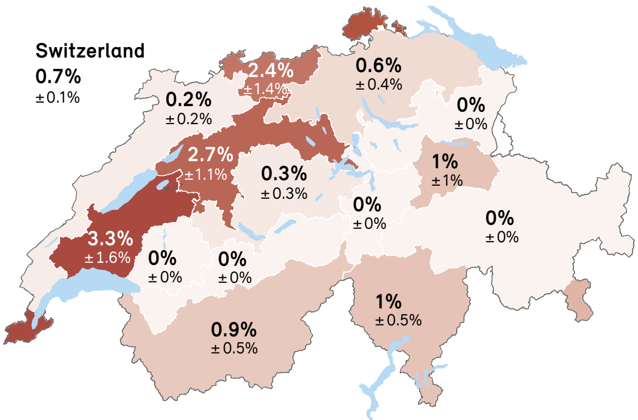
- Targeted cultivation of non-native tree species still plays a minor role in Swiss forestry. The area dominated by such species has increased by 0.2% to 0.7% over the past decade.
- Under particular environmental conditions, non-native woody species may spread invasively, especially at lower altitudes. The cultivation of non-invasive, non-native tree species is also becoming increasingly important as a climate change adaptation strategy.
- The risks and opportunities of using non-native tree species must be carefully weighed up, and invasive species management must be included in silvicultural planning.

Neophytes in the forest

Swiss flora includes around 730 established non-native plant species (neophytes) that can form spontaneous populations (FOEN 2022f). They make up 22% of all species (Lauber et al. 2018). The proportion of neophytes in other Central European countries is similar or higher. Neophytes are also thriving in forests. While some of these are non-native tree species introduced and used by the forestry sector (Conedera and Brändli 2015), other neophytes spread unchecked. If they displace native species and disrupt the balance of natural forest habitats and communities, they are considered invasive. This term refers to non-native species that pose a threat to humans and the environment or that can impair biodiversity, ecosystem services and the sustainable use of such services (FOEN 2022f). Currently, 22 woody species (trees, shrubs and lianas) are classed as invasive neophytes, while another ten are listed as potentially invasive.

Figure 4.4.1

Proportion of forest area dominated by non-native tree species in Switzerland's 14 economic regions, 2022.



Source: NFI (Abegg et al. 2023)

Cultivation of non-native tree species

Although only 0.7% of Switzerland's forest area is dominated by introduced tree species according to NFI5 (2018-26), that is 0.2% more than in NFI4 (2009–17). They occur almost exclusively at altitudes up to 1,000m a.s.l. Of these stands, 24% are located in the mid Central Plateau economic region, 17% on the southern side of the Alps, 16% in the western Plateau region and 12% each in the eastern Jura and southwestern Alps. A similar picture emerges for the proportion of these stands within the total forest area of the economic regions (Fig. 4.4.1). Douglas fir, red oak and Austrian pine are the main introduced and commercially harvested non-native tree species. The fact that they are harvested commercially allows some control over their regeneration and spread. In the Jura and on the Plateau, however, Douglas fir and Weymouth pine are showing a tendency towards spontaneous regeneration and spread (Fig. 4.4.2). While the cultivation of non-native tree species is an important source of income for forestry in some Central European countries (Conedera and Brändli 2015), the amount of timber produced in Switzerland, even of the most common of these species, such as Douglas fir, is so small that they can only exist in a small niche market. Climate change, though, could see future-adapted non-native tree species become more important (Frei et al. 2018), even assuming the principles of close-to-nature forest management, which prioritises natural regeneration and the cultivation of native tree species. However, little is known about the susceptibility of non-native tree species to native pathogens or those that may be introduced in the future. There is also a risk that such species will regenerate more frequently and unchecked and thus become invasive. The ecological and economic impacts cannot therefore yet be assessed, and more research on this is needed.

Invasive non-native woody species

Some non-native woody species that have been cultivated in Switzerland for some time as ornamental plants in private or public gardens or have proliferated on fallow land have become invasive and found their way into forests. The invasion potential of a non-native woody species depends both on the characteristics of the species in question (regeneration ecology, growth behaviour, site requirements) and on the conditions of the host ecosystem (availability of sufficient light, ability of native species to compete, presence of natural enemies) (Conedera and Schoenenberger 2014).

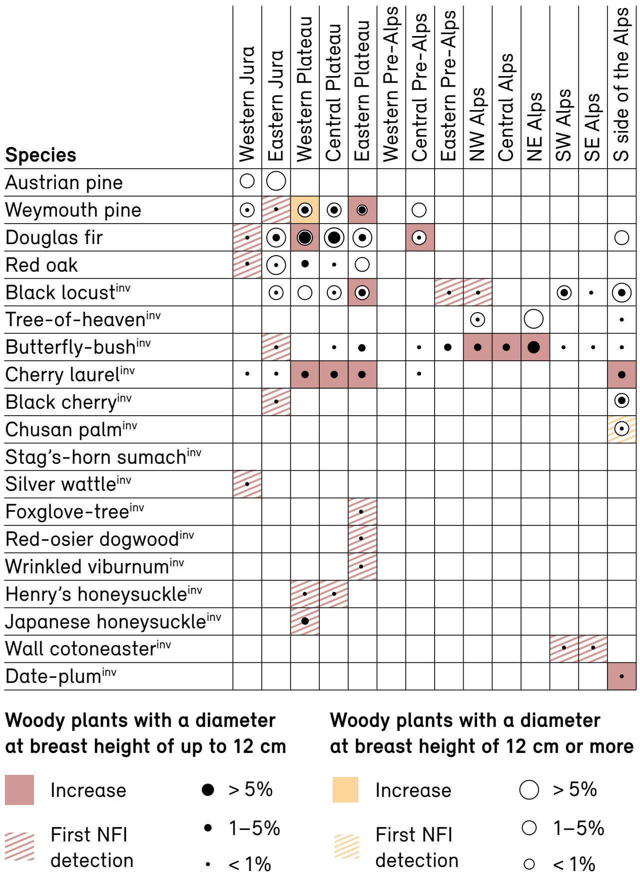
Two ecologically distinct invasion patterns are emerging in Swiss forests. The first is rapid colonisation by non-native pioneer species of areas affected by disturbances or interventions. An example is the advance of the tree of heaven, the black locust and the butterfly bush (buddleia or summer lilac), which is already being observed in several economic regions (Fig. 4.4.2). The second is the creeping penetration of thermophilic, shade-tolerant, evergreen non-native woody species into the undergrowth of deciduous broadleaved forests at lower altitudes, for example the cherry laurel and evergreen honeysuckle species in the Jura and on the Plateau.

The spread of non-native woody species is still a rare phenomenon in the wider forest context. While the NFI is designed to record major changes in the forest, even NFI sample plots are seeing significant increases in, or first detections of, non-native species in a number of regions. On the southern side of the Alps, for example, NFI5 has recorded a further spread of the cherry laurel as well as the first appearance in the forest of the Chusan palm and the date plum. Other pioneer species such as the foxglove tree and shade-tolerant, evergreen plants such as the camphor tree, bay laurel and thorny olive are also gaining ground here (Schoenenberger et al. 2014).

Non-native invasive species are therefore continuing to spread at lower altitudes in all regions of Switzerland, particularly on the southern side of the Alps, in the Jura and on the Plateau. Implementing a targeted strategy within the desired framework of close-to-nature forest management will require detailed monitoring as well as policies that take a forward-looking approach to the dynamics of these species.

Figure 4.4.2

Proportion of forest area with non-native tree and shrub species, by species, size class and region, according to data collected in NFI4 (2009–13) and NFI5 (2018–22). Significant changes and first-time occurrences on NFI sample plots are highlighted in colour. Invasive woody species as identified in the FOEN report on non-native (alien) species in Switzerland are marked 'inv'.



Source: NFI, FOEN 2022f

4.5 Deadwood

Rita Bütler, Martin Gossner, Thibault Lachat, Meinrad Abegg, Bruno Lauper

- The deadwood volume across Switzerland has increased to 32 cubic metres per hectare in the past decade, meaning that this forest policy objective has been achieved in most regions. On the Plateau, however, there is less than 20 cubic metres of deadwood per hectare in some regions.
- Both values are sufficient only for species with low deadwood requirements. Old trees with a wide variety of microhabitats and large-diameter deadwood are still too scarce. Measures are needed to promote large-diameter deadwood and old trees that complete their entire life cycle.
- The growing demand for wood could jeopardise the positive trend towards higher deadwood volumes.

Figure 4.5.1

Old trees are rare in Swiss forests. They are particularly rich in microhabitats. Photo: Rita Bütler

Importance of deadwood and habitat trees

Deadwood comprises standing and lying dead trees or tree parts of all species and dimensions and at all stages of decomposition. Habitat trees are trees with microhabitats such as rot-holes or tree-fungi fruiting bodies for certain types of beetle and cracks providing a home for bats. Over 40 tree microhabitats have been defined (Larrieu et al. 2018, Bütler et al. 2020). Old or large-diameter trees offer a greater number and diversity of microhabitats than younger trees and are therefore particularly important for forest species diversity (section 4.5.1). Around a third of forest species are heavily dependent on deadwood or habitat trees (Stokland et al. 2012), including many beetles and higher fungi, but also birds, bats, amphibians, mosses and lichens. Many species use these structures for breeding, nutrition or hibernation purposes (Graf et al. 2022). As well as being important for species diversity, deadwood also plays a key role in protection against rockfall, carbon and water storage, and natural regeneration, especially in the mountains.

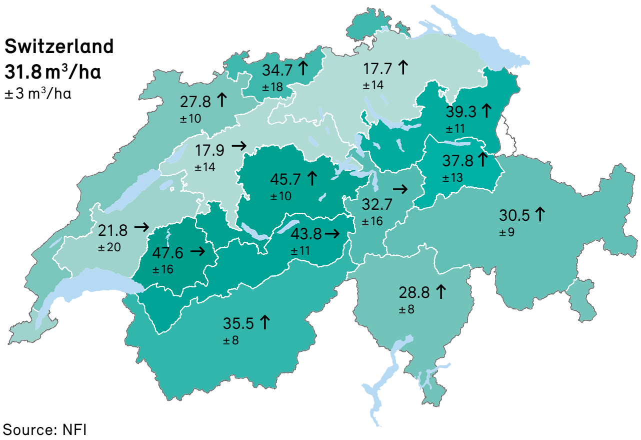
The requirements of wood-dwelling (saproxylic) species are many and varied. Deadwood must therefore be available in a variety of forms: large and small diameter, standing (as snags) and lying, sun-exposed and shaded, from different tree species, in various stages of decay and in diverse climatic conditions (Gossner et al. 2016, Seibold et al. 2016). It is important to have a large quantity of deadwood and habitat trees available in space and time, as different species rely on different stages of development and decay of tree microhabitats.

Developments in deadwood quantity

The quantity of deadwood in Swiss forests is developing positively overall (section 1.2). According to NFI5 (2018–22), the deadwood volume has expanded in many regions over the past decade and now averages 32 cubic metres per hectare (m^3/ha). However, the Plateau, the region with the least deadwood, saw only a small increase, if any (Fig. 4.5.2). Deadwood quantities in some parts of the Plateau are still below the 20m^3/ha minimum target set by the Confederation (FOEN 2021c). Most saproxylic species require larger quantities,

Figure 4.5.2

Average deadwood volume in the 14 economic regions in cubic metres per hectare (m³/ha), 2022. Changes in the past decade: ↑ significant increase; → no change.



Source: NFI

namely 30–50m³/ha in oak and beech forests, while the most demanding species need over 100m³/ha, which is similar to the levels found in pristine forests (Müller and Bütler 2010). Unmanaged forests are therefore very important for saproxylic species diversity, especially in regions with relatively little deadwood such as the Plateau. Nonetheless, only 3% of the forest area on the Plateau is unmanaged, according to the NFI (section 4.3). Specific measures such as natural forest reserves, old-growth patches and conserving habitat trees until they decompose are therefore particularly important. Fortunately, the area of natural forest reserves has increased in the past decade (section 4.9), although established forest reserves on the Plateau still naturally contain relatively little deadwood.

Swiss forests are deficient in large old trees (section 1.3). These ensure microhabitat diversity and the future supply of large-diameter deadwood (Fig. 4.5.1). Since it takes decades for trees to grow to a sufficient girth and develop specific microhabitats such as rot holes, the number of trees with a diameter of over 80cm (giants) is changing only gradually. According to the interim results of NFI5, there are between 0.3 and 3.7 giants per hectare, depending on the region. Natural forests feature around 10 to 17 giants per hectare (Nilsson et al. 2002).

Despite a slight increase, large-diameter deadwood remains rare. NFI5 also suggests that there is little heavily decomposed mouldering and mull wood debris in Switzerland; it makes up less than 20% of the deadwood volume. The lack of old trees and large stems in advanced stages of decay increases the extinction risk for saproxylic species (Monnerat et al. 2016, Gossner et al. 2013, Seibold et al. 2015; section 4.8). Without special measures to ensure that old trees remain in the forest until they decompose, many rare, specialist species are threatened with extinction in the long term. According to recent research, their loss may severely impair ecosystem functions such as nutrient recycling, pollination or soil formation (Burner et al. 2022, Brose and Hillebrand 2016). Consequently, measures to conserve rare species, such as deadwood enrichment and the promotion of old trees, have a beneficial effect on ecosystem services that has been previously underestimated.

Incentives for deadwood enrichment

The minimum deadwood volume targets set by the Confederation have largely been achieved (FOEN 2021c). However, as these are not sufficient for demanding species (Müller and Bütler 2010), the Confederation and cantons have provided financial support for around 30,000 hectares of natural forest reserves, more than 6,600 hectares of old-growth patches and around 20,000 habitat trees since 2008 (2022 figures).

The number of trees dying from drought stress has risen in the past decade. With increased demand for energy wood threatening to reverse the trend of deadwood enrichment, such extreme events could be harnessed for the benefit of biodiversity. Forest management must ensure that enough trees are left to grow old and complete their entire life cycle. The challenge will be to achieve this despite the planned intensification of wood use and the shortening of rotation periods with a view to climate change adaptation. This will require incentives both in forests and in non-forest habitats (tree-lined avenues or park and garden trees in and on the edge of settlements).

4.6 Genetic diversity

Christian Rellstab, Bruno Lauper, Felix Gugerli

- New gene conservation units have been designated in Switzerland, contributing to the dynamic conservation of genetic resources.
- Large stands and extensive gene flow mean that Swiss forest trees have a high level of genetic diversity. This is a component of biodiversity and a prerequisite for populations to be able to adapt to environmental changes and be resilient to extreme events.
- Changes in genetic diversity and adaptability over time should be monitored and analysed, and the findings increasingly incorporated into silvicultural strategies.

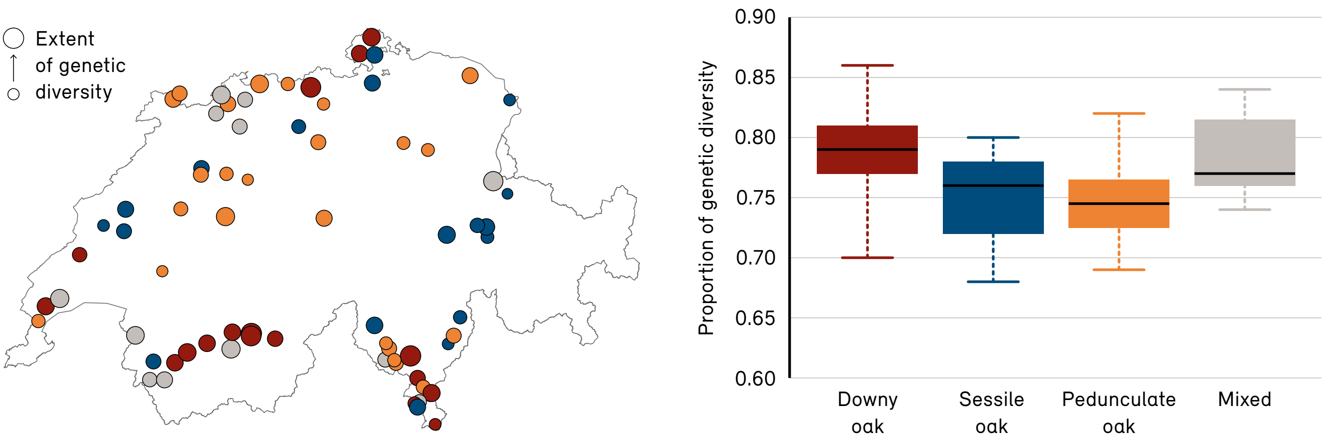
Genetic diversity of forest trees

Genetic diversity is considered the cornerstone of biodiversity and is a prerequisite for species and populations to be able to adapt to changing environmental conditions, thereby increasing the resilience of forests to extreme events such as drought and pest infestation. A high level of genetic diversity is therefore essential if Swiss forests are to continue performing their functions in the future.

Most tree species have a high level of genetic diversity thanks to large, close-to-nature stands, extensive gene flow through pollen and seed dispersal and mostly natural regeneration. This is exemplified by the native oaks (sessile, downy and pedunculate), which have a similar level of genetic diversity in all regions of Switzerland (Rellstab et al. 2016; Fig. 4.6.1a). Mixing through natural cross-breeding and back-crossing over many generations have increased the diversity in this species complex. For example, downy oaks, which often hybridise with sessile oaks, have a higher genetic diversity than pure stands of sessile or pedunculate oaks (Fig. 4.6.1b).

Figure 4.6.1

a) Genetic diversity of 71 oak stands, measured using heterozygosity (average proportion of individuals with different gene variants at a particular position in the genome). The size of the circles corresponds to the level of genetic diversity and the colours indicate the oak species. b) The box plot summarises the heterozygosity for stands of the same species (bold black line = median, box = range in which the middle 50% of all values lie; whiskers: maximum or minimum value). Mixed stands: the dominant species makes up a maximum of 80% of the stand.



Source: Rellstab et al. 2016

Technical advances mean that it is possible to determine which part of the genetic diversity influences the adaptability of trees and their offspring to local environmental conditions (Gugerli et al. 2016). Studies on Arolla (or Swiss stone) pine stands, for example, have shown that the change in adaptation-relevant diversity can barely keep pace with rapid climate changes (Dauphin et al. 2021). Long-lived forest tree species with a long generation time are therefore at particular risk from climate change.

Protection of genetic resources

As a Forest Europe signatory state and a member of EUFORGEN (European Forest Genetic Resources Programme), Switzerland has made an international commitment to protect its forests' genetic resources. These resources are conserved and promoted through numerous measures including natural regeneration (section 4.2) and forest reserves (section 4.9).

Since 2016, Switzerland has also designated 74 gene conservation units (GCUs) for seven species, including stands of Swiss pine and yew; Switzerland is a main area of distribution for the latter two species (Table 4.6.1). GCUs are mostly forest reserves in which genetic diversity is to be conserved through natural processes. The selected populations are autochthonous, have a minimum stand size and represent the distribution, the different environmental conditions and – where known – the genetic groups of the species (Rudow 2016). In the near future, GCUs are to be designated for sycamore, ash, larch, Scots pine and sessile, pedunculate and downy oak.

For many tree species Switzerland has seed-harvesting stands, i.e. forest stands where seed is obtained to grow saplings. These stands were chosen based on criteria such as the growth or shape of the parent trees. These criteria, combined with the common practice of harvesting from only a few parent trees, limit the genetic diversity of planted trees. Seed-harvesting guidelines concerning the minimum number of parent trees and of seeds per parent tree are needed to increase the genetic diversity of the planting material. Seed harvesting could also be expanded to include GCUs.

Climate change strategies

Climate change is a reality and will affect Swiss forests for a long time to come. The speed at which the climate is becoming warmer and at times drier could pose problems for long-lived forest trees in particular. Individual adult trees can respond to changing environmental conditions (plasticity), but the genetic composition of stands changes only gradually. Possible action includes promoting a high genetic diversity at stand level but also specifically encouraging genetic variants whose carriers are adapted to warmer and drier conditions. Genetic analyses help to quantify genetic diversity and estimate the degree of genetic adaptation of a species. They should be given a greater role in the development of silvicultural strategies.

Table 4.6.1

Gene conservation units in Switzerland. Some areas contain GCUs for multiple species.

Species	Number of gene conservation units	Number of cantons involved	Area (ha)
Swiss pine	10	6	3122
Beech	13	12	7364
Yew	10	10	1989
Wild service-tree	9	8	1363
Spruce	14	11	11 137
Black poplar	5	5	912
European silver fir	13	11	7119
Total	**62**	**20**	**23 901**

Source: Nationaler Generhaltungsgebiete-Kataster (NGK), situation at 31.10.2022.

4.7 Forests in the landscape

Christian Ginzler, Matthias Bürgi, Bruno Lauper

- Forest areas in the Alps and on the southern side of the Alps continue to expand and small patches of forest in these regions are merging. However, growth has slowed. On the Plateau, forest area and distribution are stable.
- At altitudes of 600 to 1,400m a.s.l., 80% of open areas have small structural elements such as individual trees and hedges. This contrasts with lower altitudes, where over a third of the landscape is cleared.
- The challenge in the coming decades will be to better connect forest areas by means of groups of trees and individual trees on open land, thereby enhancing the ecological infrastructure.

Changes in forest patterns

Approximately a third of Switzerland is forested. The pattern of the forest, i.e. the number of forest patches and their distribution, has changed. Land Use Statistics show that large forest areas have increased since the 1980s, although the changes have varied from region to region. On the Plateau, both the area and distribution of forests have remained very stable due to intensive land use and the high demand for land. By contrast, forests in the Alps and on the southern side of the Alps have grown in size and merged. Forest has been able to expand and encroach onto open land at higher altitudes where agriculture has been abandoned.

The landscape is characterised not only by the proportion and distribution of forest but also, and to a large extent, by woodland fragments outside the forest area (Fig. 4.7.1). The forest area is often adjoined by structurally rich pieces of land featuring copses, hedges and bushes, which are of high value both ecologically and in terms of landscape aesthetics. Results from the Landscape Monitoring Switzerland programme (LABES) show that these transitional zones have been generally diminishing since 1985 and that the distance between forests and settlements is becoming ever smaller due to the expansion of the latter (FOEN/WSL 2022).

Figure 4.7.1

Large parts of the open countryside, as here near Bärschwil (SO), are interspersed with woody elements and are thus well interconnected. Photo: Simon Speich

Forests and trees as part of the ecological infrastructure

Woody elements in the landscape are key components of the ecological infrastructure. These small structures, such as single trees, rows of trees and forest edges, act as stepping stones forming links within the landscape. Analyses of the Swiss topographic landscape model (TLM) reveal that many parts of Switzerland are well supplied with such features (swisstopo 2023). Thus, 80% of open land at altitudes between 600 and 1,400m a.s.l. includes woody elements. Above 1,400m a.s.l., woodland fragments are less important to the integrity of the ecological infrastructure. By contrast, at altitudes below 600m a.s.l., where agriculture is more intensive, over a third of the land is cleared and offers scope for structural improvements.

4.8 Endangered species

Andrin Gross, Silvia Stofer, Timothy Thrippleton

- Red Lists form the basis for assessing the threat situation for forest species. They show a stable to slightly positive trend in the number of endangered forest species.
- Swiss forests are species-rich and are home to a large number of rare and endangered species.
- Against the backdrop of future challenges such as climate change and energy supply, targeted monitoring programmes for rare species are vital for identifying negative developments at an early stage.

Basis for forest species protection

In the past decade, new and revised Red Lists have provided an important basis for the promotion of forest species. The synthesis report on the Swiss Red Lists published to date shows that, in the case of plants, the proportion of endangered species in forests is relatively low compared with other habitats, at around 13% (FOEN and InfoSpecies 2023). However, as Switzerland's forests are species-rich, they are home to the most endangered species in absolute numbers (Gubler et al. 2020). Of the forest communities, 41% are classed as endangered on the Red List (Delarze et al. 2016), with those in moist and open forest areas particularly at risk. While moist forests have declined as a result of land development and drainage, open forest structures have been decimated for other reasons: discontinuation of timber harvesting e.g. from forest pastures, the change to high forest management, an increase in growing stock due to reduced harvesting, excessive nitrogen deposition and the suppression of open pioneer and old-growth phases.

The first Red List of jewel beetles, longhorn beetles, flower chafers and stag beetles painted a worrying picture of the threat facing these insects (Monnerat et al. 2016). Of the 256 predominantly wood-dwelling beetle species, almost half (118) were endangered, with another 47 considered potentially endangered (18%). The species assessed are only a small proportion of the 1,700 or so beetle species that rely on deadwood (Lachat et al. 2019).

Deadwood is very important for forest biodiversity (section 4.5), with no fewer than a third of all forest species dependent on it, in particular beetles and around 2,700 species of fungi (Lachat et al. 2019), as well as birds, bats, amphibians, mosses and lichens. Many of the endangered species have specific quality requirements in terms of the host plant, the stage of decomposition or the position of the deadwood (upright or lying). One example is the great capricorn beetle *(Cerambyx cerdo)* (Fig. 4.8.1). Now threatened with extinction, it needs very old oaks with dying and dead wood, which are often unavailable in sufficient quantities in managed forests (FOEN and InfoSpecies 2023). As well as the lack of deadwood in some regions, species diversity is adversely affected by the reduced size of areas containing special forest communities, open stands and stands in the old-growth stage.

Figure 4.8.1

The great capricorn beetle is at risk of extinction in Switzerland. It lives on very old oaks, which are rarely found in managed forests. Photo: Beat Wermelinger

New risk factors
Based on the available data, it is difficult to assess how the threat situation has evolved over the past decade. Swiss Biodiversity Monitoring (BDM) shows a slightly positive trend for a number of forest species, specifically snails, mosses and vascular plants (Birrer et al. 2022; section 4.1). However, no conclusions can be drawn from this about endangered species. Revised Red Lists have been published for mosses, plants and birds (Knaus et al. 2021, Bornand et al. 2016). These indicate only minor changes for birds and vascular plants. While a positive trend has been detected for mosses, this has not yet been confirmed owing to methodological uncertainties.

The greatest threats to biodiversity come from energy supply developments (Lachat et al. 2019) and climate change (Pluess et al. 2016). Growing demand for wood as an energy source (section 6.7) could negatively impact the amount of old growth and deadwood in forests. Integrated efforts to promote deadwood in close-to-nature forest management are therefore vital for biodiversity (section 4.5). Climate change, meanwhile, is resulting in more frequent extreme events such as droughts and storms and more disturbances in forests (section 2.5). These can have a positive effect on biodiversity, for example by creating a mosaic of different succession stages on disturbed land and so enhancing habitat diversity. However, climate change is increasingly affecting the foundations of life for many species and further increasing the extinction risk for endangered species (IPBES 2019b). Against this backdrop, monitoring programmes such as the NFI, BDM and the monitoring of structural and species diversity in Swiss natural forest reserves are becoming ever more important. By helping to track the development of forest biodiversity, they act as an early warning system for negative trends.

Conservation measures and monitoring
Close-to-nature forest management (section 4.3), the designation of forest reserves (section 4.9) and other targeted measures can strategically promote forest biodiversity. Funding has been available for this since 2008 under the programme agreements between the Confederation and cantons (Stadler und de Sassi 2021). Outcome evaluations show that these measures are having a marked impact, especially for rare species in open forests and for deadwood beetles (Bühler und Roth 2021). In the canton of Geneva, for example, tree fungi such as the critically endangered flame shield *(Pluteus aurantiorugosus)* (Fig. 4.8.2) have been given a boost by the placing of tree trunks (FOEN and InfoSpecies 2023). InfoSpecies' Open Forest Action Plan is also a major step towards promoting endangered species (Imesch et al. 2020). It includes an online tool that assists both forestry agencies and cantonal officials responsible for forest biodiversity with planning and implementing nature conservation measures in forests. A further instrument is cantonal planning to establish a series of protection and connectivity areas (FOEN 2021a), intended to create space for long-term biodiversity conservation.

There is also a virtual data centre providing cantons with a comprehensive analysis of current and target habitat status. These new planning tools help to promote successful and effective nature conservation planning at cantonal level.

Figure 4.8.2
The flame shield fungus lives on decayed stems of broadleaved trees in alluvial forests. In the canton of Geneva, it has been given a boost by the placing of tree trunks. Photo: Julia Jenzer

4.9 Forest reserves

Martina Hobi, Harald Bugmann, Martin Gossner, Thibault Lachat, Bruno Lauper

- In 2022, the proportion of forest reserves within the total forest area reached 7.3%, meaning that the Forest Policy target of 10% reserve area by 2030 was already almost three-quarters achieved.
- Natural forest reserves have a positive impact on the number and distribution of deadwood-dependent species, with the number of endangered fungi species higher in reserves than in managed forests.
- In the designation of future forest reserves, even greater consideration is to be given to the promotion of National Priority Species and Habitats and a better connected spatial distribution of reserve areas.

Status of forest reserve policy

In the 2001 Forest Reserve Policy Guidelines and the Forest Policy 2020, the Confederation and cantons have set themselves qualitative and quantitative targets for the designation of forest reserves. They also remunerate forest owners for this public good. Switzerland has two types of forest reserve: natural forest reserves (NFRs), in which no forest management at all takes place, and special forest reserves (SFRs), in which habitats for selected animal and plant species are created and specifically promoted through targeted interventions. Both types of reserve serve to promote biodiversity, while NFRs also help to safeguard natural ecological processes. The Confederation and cantons intend to designate 10% of the forest area as reserves by 2030, with NFRs and SFRs making up 5% each. In 2022, according to surveys by the Federal Office for the Environment (FOEN), NFRs accounted for 4.16% of the national forest area and SFRs for 3.18% (FOEN NFE Controlling), bringing the total proportion of forest reserve to 7.3%. Just 20 years ago, forest reserves made up only around 2.5% of the forest area. In this respect, the federal and cantonal forest reserve policy has been very effective so far, although distribution varies from region to region (Fig. 4.9.1), with fewer protected forest areas on the Plateau than in the Jura, the Pre-Alps and the Alps.

While the forest reserve policy's quantitative targets are achievable by 2030, meeting the qualitative goals will be a greater challenge. In forest reserves, common forest communities are well represented in terms of the share of the area they occupy compared with their overall occurrence nationwide. However, the reserves still fall well short when it comes to National Priority Habitats particularly worthy of conservation, especially those with moist conditions (Steiger 2014). Nonetheless, there has been success in promoting National Priority Species, with the designation of SFRs for the capercaillie and the middle spotted woodpecker. Both are considered umbrella species, whose conservation benefits many other animal and plant species in the same habitat.

The size of forest reserves has also seen significant progress in the past decade. With 39 designated large reserves in 2022, the original target of at least 30 large forest reserves of over 500 hectares has already been exceeded. However, here too there are big regional variations. On the Plateau especially, creating large reserves is harder because forest areas tend to be more fragmented and wood harvesting is more attractive owing to better accessibility. Most large reserves are located in mountainous and difficult-to-reach areas. That said, there have been some major successes even on the Plateau, with the establishment of the Sihlwald Nature Discovery Park in the canton of Zurich and the Parc du Jorat in the canton of Vaud. Most reserves are relatively small, however, averaging 43 hectares in size. Having a mix of small and large reserves is important: small reserves represent the diversity of habitats, while large reserves allow natural forest development and conservation measures at landscape level. In addition, forest reserves function as ecological core areas which are crucial for nationwide habitat connectivity.

Insights from natural forest reserves

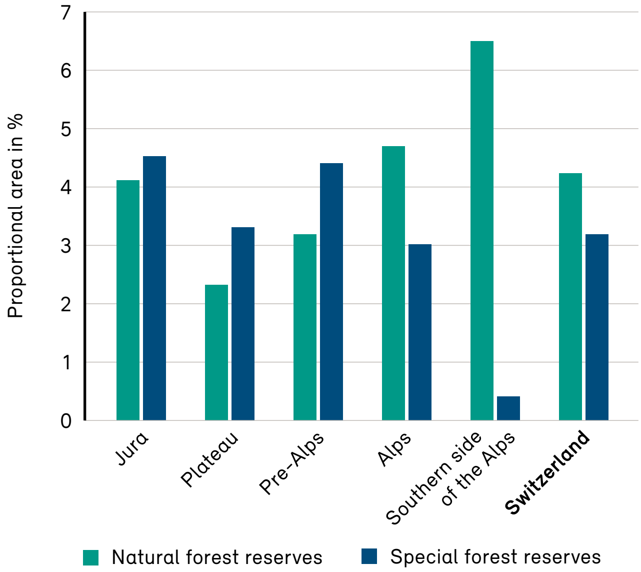
Long-term monitoring of natural forest reserves (NFRs) provides insights into how forests develop naturally without anthropogenic influences (Fig. 4.9.2). Since observations began in the 1950s, the growing stock of living trees and the amount of standing deadwood as well as the number of habitat trees have increased significantly in most NFRs (section 4.5), as the protected forests develop into natural forest. The total amount of carbon stored in NFRs also continues to rise. Species dependent on old growth and deadwood benefit accordingly (Roth in prep.). The species diversity of wood-dwelling beetles and fungi is higher here than in nearby managed beech forests, and habitat quality for wood-dwelling species improves the longer NFRs are not managed or used. The diversity of different species communities is also higher than in managed forests, with more endangered fungi species observed in the NFRs.

Conservation measures in special forest reserves

Special forest reserves (SFRs) are characterised by silvicultural interventions to promote biodiversity. They also seek to conserve and promote historical forms of management such as coppices, wooded pastures and nut orchards. Many light- and warmth-demanding species rely on such open forests, having experienced a sharp deterioration in their environmental conditions in the second half of the 20th century (Imesch et al. 2020). In SFRs, gradually opening pine forests can help boost various butterfly, reptile and orchid species, while in coniferous forests in the Alpine regions, special efforts can be made to maintain open structures such as clearings, which are important for species like grouse to thrive. Since 2015, several thousand hectares of SFR have been established for capercaillie, for example. Gene conservation units can also be set up in SFRs for selected native secondary tree species whose protection requires targeted silvicultural interventions (section 4.6).

Figure 4.9.1

Proportional area of natural forest reserves and special forest reserves in the production regions and in Switzerland as a whole, 2022.



Source: FOEN, adapted from Impuls 2023

Figure 4.9.2

The Scatlè natural forest reserve near Brigels (GR) has plenty of deadwood and natural regeneration. Photo: Gilbert Projer, WSL

4.10 Forest breeding birds

Alex Grendelmeier, Kurt Bollmann, Pierre Mollet, Timothy Thrippleton

- The populations of most forest bird species have developed positively over the past decade.
- However, a few species, such as the wood warbler and the grey-headed woodpecker, have become rarer. These species are habitat specialists, so their decline indicates a lack of suitable habitat.
- The intensification of management with shorter rotation periods and the increasing demand for energy wood could jeopardise the positive trend.

Populations of forest bird species
Bird population numbers are used in environmental monitoring as an indicator for biodiversity status and development. This is because birds are widespread, can be recorded easily and react strongly to environmental changes.

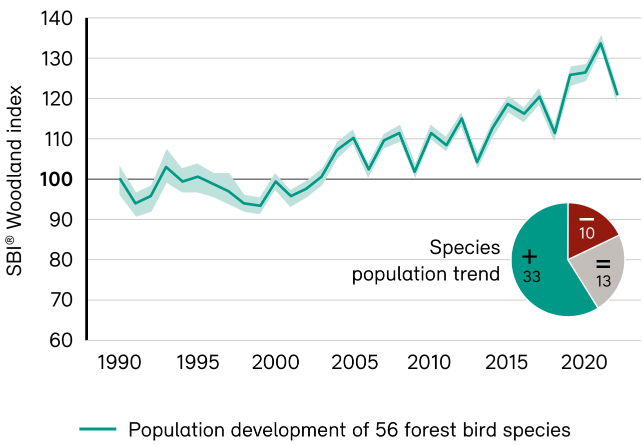
The Swiss Ornithological Institute calculates the Swiss Bird Index SBI® based on the population trends of breeding bird species (Knaus et al. 2022). The SBI® Woodland sub-index summarises the trends for 56 native forest bird species. It includes all species that breed mainly in forests and that have bred in Switzerland at least once in nine out of ten consecutive years since 1990.

The SBI® Woodland shows that populations of forest bird species have developed positively since 1990 and especially in the past decade (Fig. 4.10.1). As well as generalists such as the great tit, which is not limited to a particular habitat, all woodpecker species except the grey-headed woodpecker *(Picus canus)* have shown positive trends. Woodpecker holes also benefit other cavity-nesting birds such as the stock dove *(Columba oenas)* and the Eurasian pygmy owl *(Glaucidium passerinum)*.

While the SBI® Woodland does not allow any conclusions to be drawn about trends in endangered breeding bird species, even some forest bird species are seeing their populations decline, suggesting a lack of suitable habitats. The capercaillie *(Tetrao urogallus)*, for example, requires undisturbed, open coniferous stands, while the wood warbler *(Phylloscopus sibilatrix)* prefers old, closed broadleaved stands with a minimal shrub layer. Diverse or traditional management systems such as wooded pastures in combination with forest reserves lead to greater species diversity.

The positive population development of many forest bird species is the result of rather extensive forest management in recent years, the increase in forest reserves and the promotion of old growth and deadwood in managed forests. However, growing demand for construction timber and energy wood and a shortening of rotation periods threaten to reverse the current favourable population trends for many species.

Figure 4.10.1
Average population development of 56 forest bird species according to the SBI® Woodland (green line; green area = 95% confidence interval). For example: a value of 120 means that the population in the year in question was 20% above the 1990 value. The pie chart shows the number of species that have increased (33) and decreased (10) in population, and those where there is no clear trend (13).



Source: Swiss Ornithological Institute 2023

5

Protective Forest

In the mountains, forests perform a vital protective function for people and infrastructure: Protection forest near Vals (GR).

Photo: jackmalipan iStock

5 Protective Forest

Barbara Allgaier Leuch, Peter Bebi, Benjamin Lange, Stéphane Losey

In Switzerland, 44% of forest protects people and infrastructure from gravitational natural hazards such as rockfall, avalanches and debris flows. Protective forests have become denser over the past decade, improving the protective effect. However, they have also got darker as a result. The lack of light and high levels of ungulate browsing prevent regeneration, meaning that in many places the protective effect is not guaranteed in the long term and takes longer to restore after a disturbance. Targeted regeneration interventions and adapted wildlife management can counteract this by achieving greater tree-species diversity, thereby ensuring protection against natural hazards even in a changing climate. Forests also protect groundwater, an important source of drinking water, from contamination. Groundwater from forest areas usually contains so few pollutants that it can be used as drinking water without treatment. However, in some places even forest groundwater exceeds the nitrate concentration limit of 25 milligrams per litre. To lower the nitrate concentration in groundwater and thus in drinking water, nitrogen deposition from the air must be reduced.

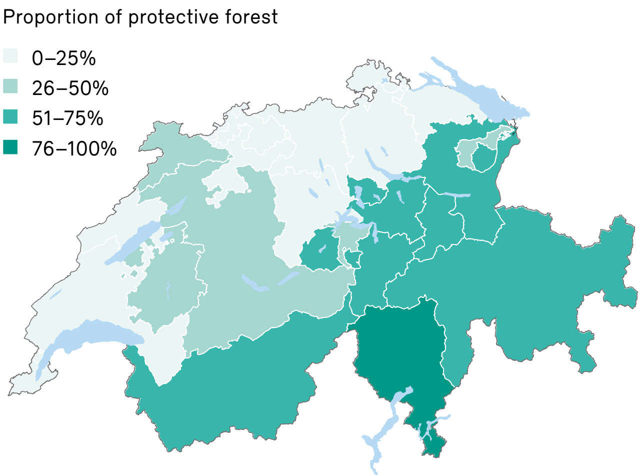
5.1 Protection against natural hazards

Peter Bebi, Benjamin Lange, Barbara Allgaier Leuch, Stéphane Losey

- The proportion of protective forest with little regeneration has risen again in the past decade as protective forests have become denser and browsing by wild ungulates has remained high.
- According to the National Forest Inventory, 44% of Swiss forest is classed as protective forest, meaning that it protects people and physical assets from natural hazards such as landslides, avalanches, rockfall or debris flows.
- Increasing disturbances due to climate change will reduce the protective effect of forests in some areas. In order to minimise such adverse effects, the resilience of protective forests must be enhanced.

Figure 5.1.1

Proportion of protective forest in the cantons, 2022. Nationwide, 44% of forest is classed as protective forest.



Source: NFI (Abegg et al. 2023)

Definition and extent of protective forest

Landslides, avalanches, rockfall and channel processes such as debris flows or overbank sedimentation are natural hazards that can cause significant damage to infrastructure and cost lives. In Switzerland, forest that protects against such hazards or reduces the associated risks is classified as protective forest. Protective forests are designated by the cantons based on the criteria defined in the SilvaProtect-CH project, which apply throughout Switzerland (Losey and Wehrli 2013). Forests that merely reduce water runoff do not meet the conditions for protective forest status.

In 2022, around 540,000 hectares, or 44% of the accessible forest defined in the National Forest Inventory (NFI), excluding shrub forest, was classified as protective forest (Abegg et al. 2023). It is the main natural-hazard prevention measure in terms of area and a key component of integrated risk management. In many places, the presence of forests avoids the need for expensive protective measures such as avalanche barriers, rockfall protection nets and sediment retention basins.

Protective forests have been designated in all parts of the country. The largest areas are in the Alpine cantons (Fig. 5.1.1). On the Plateau, the proportion of protective forest is comparatively low, but, this being a densely populated region, the forests here protect an especially large number of people and infrastructures.

Protection against natural hazards

Some 25% of protection forest protects people and infrastructure from shallow landslides, 19% from avalanches, 8% from rockfalls and 85% from channel processes such as debris flows, overbank sedimentation or bank erosion (Abegg et al. 2023). Almost 30% protects against multiple natural hazards simultaneously, which also explains why the total protective effects add up to more than 100%. Forests' protective effect relies on different mechanisms depending on the natural hazard. Tree root systems are key to preventing landslides as the roots reinforce the soil while also drawing water out of it. Protective forests prevent avalanches by stopping unstable snow layers from building up around the trees. In the case of rockfall, the trees slow down, or even stop, falling rocks, while in channel processes, the forest structure influences the amount of debris and driftwood that enters streams and rivers.

Tending protective forests

The effectiveness of a protective forest depends heavily on its structure and stage of development and can therefore change over time. To ensure a long-term protective effect, most protective forests require targeted tending operations to improve their structure and regenerate them sustainably. Adapting the tree species composition to the changing climate is also an important task. The type and frequency of interventions depend on the natural conditions, the threat of natural hazards and the assets to be protected, as well as on the development history and current condition of the protective forest concerned.

In the past decade, around 93,000 hectares of protective forest nationwide have been tended, equivalent to around 17% of the total protective forest area (Abegg et al. 2023). The percentage of area tended varied by region: on the Plateau, 41% of the designated protective forest was tended (10,000ha), compared with 34% (11,000ha) in the Jura, 25% (29,000ha) in the Pre-Alps, 17% (40,000ha) in the Alps and 3% (3,000ha) on the southern side of the Alps. The differences can be explained primarily by the relative inaccessibility of protective forests in the Alps and on the southern side of the Alps, as well as by differences in growth rates. In addition, specific forest protection measures were implemented in around 38,000 hectares of protective forest throughout the country (Abegg et al. 2023). For example, beetle-infested or recently wind-thrown spruces were removed to contain the spread of the bark beetle. The area requiring such protection measures has increased by 60% in the past decade owing to exceptional drought periods from 2018 onwards and storm events.

The costs of tending protective forests are borne by the Confederation, cantons and other beneficiaries (communes, infrastructure operators, etc.). The services to be provided, the associated quality criteria and the financial conditions are regulated by the Confederation and the cantons in programme agreements, under which the Confederation contributes to the costs of protective forest tending and the infrastructure this requires, as well as of forest protection measures.

Tree species composition and stand density

The tree species composition of many protective forests has been shaped by previous management practices (section 4.3). Spruce, which naturally thrives mainly at higher altitudes, was also heavily promoted at low and medium altitudes until the 1980s. Accordingly, a comparison of the stands on NFI sample plots with the forest site types developed in the Sustainability and Success Monitoring in Protective Forests (NaiS) project (FOEN 2024, ARGE Frehner 2020) shows that the proportion of spruce in protective forest, especially beech, fir/beech and fir/spruce forests, is higher than in natural forest (Abegg et al. 2023). However, spruce-dominated forests are particularly susceptible to drought, bark beetle infestation and other disturbances. This can weaken the protective effect against natural hazards. Climate change also increases the risk of disturbances with subsequent temporary loss of protective effect as it makes even tree species growing in their natural range more vulnerable.

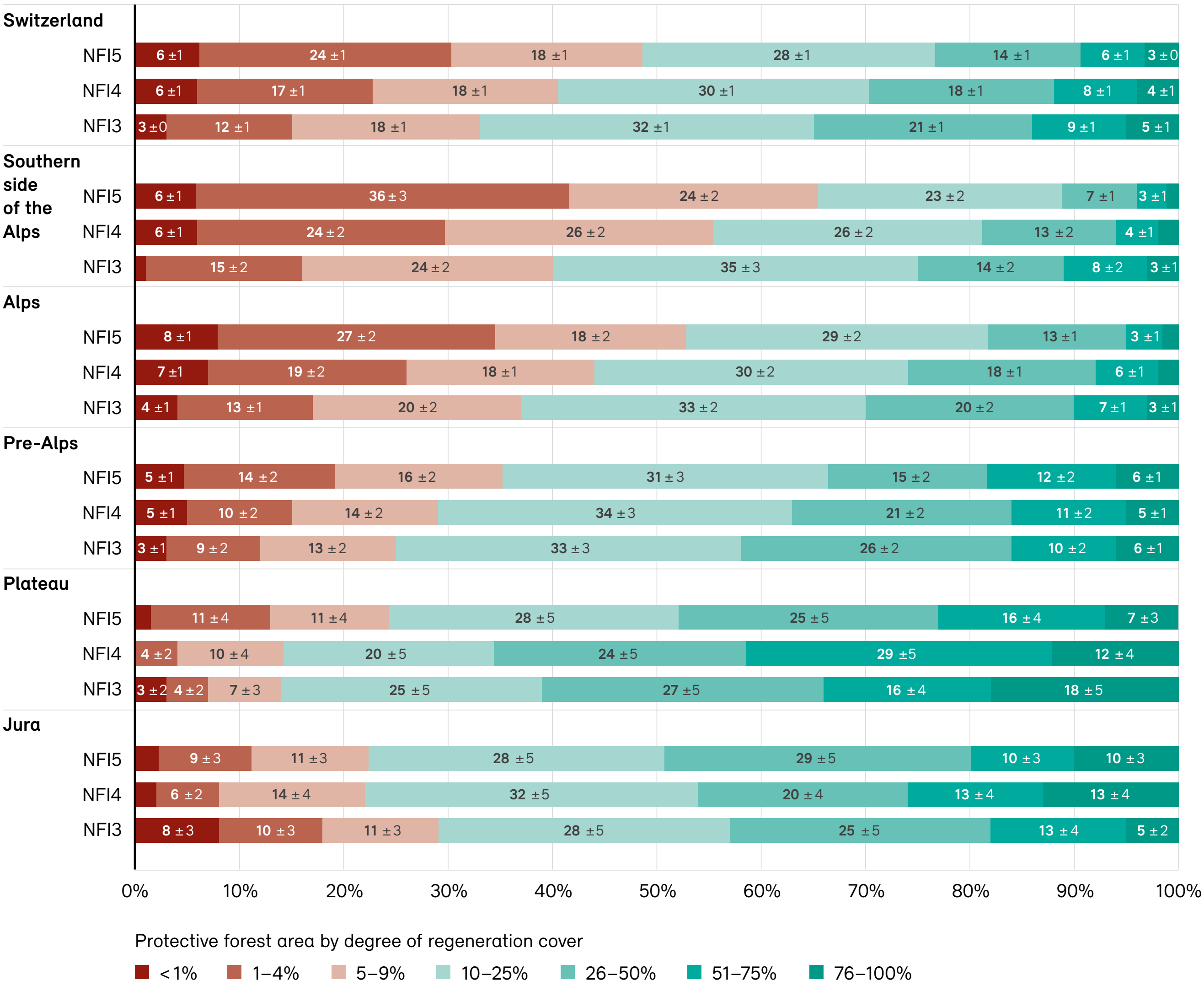
Protection forests have become denser overall in the past decade (Abegg et al. 2023). In all parts of the country, open and scattered stands have decreased and forests with a crown coverage of over 80% on aerial photographs have increased. In the Alps and on the southern side of the Alps, growing stocks have also continued to expand, increasing by 5% in the Alps, to around 360 cubic metres per hectare, and by 13% on the southern side of the Alps, to 290 cubic metres per hectare (Abegg et al. 2023; section 1.2). Although such densification reflects successful forest development and enhanced protection against natural hazards over recent decades, this trend has to be viewed critically in terms of the diversity of stand structures and continuous regeneration. Both of these factors are crucial in maintaining the protection effect long term and in adapting protective forests to climate change.

Stand structure and regeneration

Both single-layered protective forests and those with little regeneration have become more common in the past decade (Abegg et al. 2023; section 1.3). Throughout Switzerland, almost 40% of protective forest is now single-layered. On the southern side of the Alps, the proportion of single-layered stands is higher than the national average, at 44%, while in the Jura and on the Plateau it is significantly lower, at 24% and 30% respectively. Single-layered stands with a lack of secondary growth (young trees) are particularly unfavourable as they recover slowly after a disturbance. Overall, the proportion of protective forest with little regeneration (regeneration cover of less than 5%) has increased and now accounts for 30% of the total protective forest area (Fig. 5.1.2). Here too, there are large regional differences. In the Jura and on the Plateau, around 12% of the protective

Figure 5.1.2

Proportional degree of regeneration cover in protective forests in NFI5 (2018–22), NFI4 (2009–17) and NFI3 (2004–06) in the five production regions and in Switzerland as a whole.



Source: NFI

forest area has low levels of regeneration, compared with 19% in the Pre-Alps, 34% in the Alps and 41% on the southern side of the Alps.

There are a variety of reasons for the sharp rise in the proportion of protective forest with little regeneration (section 4.2), for example reduced light availability due to increasing forest density and the continuing high level of browsing of young trees by deer and chamois. The results of NFI5 (2018–22) found that the top shoot of 18% of young trees in protective forests, i.e. almost one in five trees between 10cm and 129cm tall, had been eaten off in the previous year (Abegg et al. 2023). On the southern side of the Alps, 29% of young trees had been browsed. Particularly affected are fir (31%), maple (24%) and oak (25%), three key species for the future in terms of climate change adaptation.

Climate-adapted protective forest

The rapid advance of climate change poses new challenges for protective forests and their management. Tree species that play a key role in protective forests are increasingly suffering from heat and drought stress. Also, climate change combined with an expansion of growing stock in some areas increases the risk of large-scale disturbances such as windthrow, bark beetle infestation or forest fires. To ensure that protective forests can continue to provide the required protection, their adaptation to the changing climate must be supported and their resilience enhanced. Regeneration cutting, for example, can increase the availability of light in dense and structurally uniform protective forest stands and promote natural regeneration, while also countering the trend towards single-layered stands. Interventions must promote tree species diversity in general and future-adapted tree species in particular (oak in beech stands or fir in spruce stands), e.g. through natural regeneration and possibly also through planting. It is also important to minimise the impact of ungulate browsing on young trees so that they can grow to maturity. Disturbances reduce the protective effect of forest in some areas as a result of trees dying or large gaps being formed in the protective forest. Targeted encouragement of advance regeneration enables reforestation after windthrow and/or beetle infestation to take place more quickly because new trees are already present under the main stand. If, in addition, standing or lying dead trees are left in situ, a residual protective effect against avalanches and rockfall is maintained. In the longer term, this measure leads to better forest regeneration as decayed wood forms a favourable seedbed (Fig. 5.1.3).

Figure 5.1.3

Protective forest above Bonaduz (GR). Diverse stands with sufficient light, a variety of tree species and deadwood enhance the forest's resilience. Photo: Peter Bebi

5.2 Drinking water

Barbara Allgaier Leuch, Sabine Braun, Katrin Meusburger, Simon Tresch, Miriam Reinhardt, Peter Waldner, Oliver Wolf

- The groundwater from forest areas is usually of such good quality that it can be fed into the drinking water network without further treatment.
- Levels of nitrate leaching from forest soils have hardly changed in the past decade. However, they can be high in some localities, indicating an excessive nitrogen load.
- In order to lower nitrate concentrations in seepage water and thus in drinking water from forest areas, nitrogen deposition from the air must be reduced. Silvicultural measures that strengthen forests' resilience can also reduce the risk of nitrate leaching after disturbance events.

As the structure of the Forest Report is based on the Forest Europe criteria for sustainable forest management in Europe (Forest Europe 2020), the role of forests in supplying clean drinking water is dealt with in the chapter on protective forest. In Switzerland, forests from which drinking water is extracted are not designated as protective forests. The term 'protective forest' is reserved for forest areas that protect people or physical assets from natural hazards (section 5.1).

Drinking water protection in forest areas

Around one billion cubic metres of water are fed into the drinking water network every year, 20% of which comes from lakes and 80% from groundwater (SVGW 2023). Groundwater from forested catchment areas is generally of such good quality that it can be used as drinking water without treatment (FOEN 2019b). The first reason for this is that fertiliser and pesticide use is generally prohibited in forest management. Exemptions are granted only for individual, clearly defined situations, e.g. treating round stack wood at storage sites with insecticides for bark beetle (Annexes 2.5 and 2.6 to the Chemical Risk Reduction Ordinance of 18 May 2005, ORRChem, SR 814.81). Secondly, the usually permanently dense forest vegetation and the generally undisturbed forest soil absorb a considerable proportion of the pollutants deposited via the air, preventing them from reaching the groundwater.

The cantons are required to determine zones around groundwater wells to protect drinking water from immediate hazards (Article 20 of the Federal Act on the Protection of Waters of 24 January 1991, WPA, SR 814.20). These groundwater protection zones entail restrictions on use. For example, in forests, in protection zones S1 (catchment zone), S2 (inner protection zone) and Sh (protection zone with high vulnerability), round stack wood lying at storage sites cannot be treated with insecticides (Annex 2.5 ORRChem).

An analysis of the National Forest Inventory (NFI) data shows that groundwater protection zones covered an area of almost 250,000 hectares in Switzerland in 2022 (Abegg et al. 2023). About half of this was in forests, and half on open land. As forests cover only around a third of the country's surface area, the relative proportion of groundwater protection zones in forests (around 10% of the total forest area) is significantly higher than on open land (4%). This is not surprising as water supply companies favour forested areas, where the groundwater is high quality and so the costs of obtaining drinking water are significantly lower. However, restrictions on use can mean additional costs or reduced yields for forest managers.

Nitrate leaching from forest soils

Nitrate concentration is an important factor in assessing drinking water quality. Where levels are elevated, risks to human health cannot be ruled out (Rohrmann et al. 2021). Drinking-water intake facilities in agricultural areas usually contain higher levels of nitrate than those in forest areas. Groundwater from agricultural areas is therefore often mixed with water from forest areas to reduce the nitrate content. Nitrate concentrations can also be elevated in forests, especially where there is high nitrogen deposition from the air, which largely originates from agriculture (section 2.1). If the nitrogen load is excessively high, nitrate is leached out of the forest soil (CLRTAP 2017b, Bobbink et al. 2022). This can lead to nutrient loss and thus to soil acidification (section 2.2) as well as to nitrates entering the groundwater.

Groundwater quality is influenced by seepage in forest soils. Long-term measurements from 2002 to 2022 on Long-Term Forest Ecosystem Research (LWF) and Intercantonal Forest Observation Programme (WDB) study sites found that the annual maximum nitrate concentrations in seepage water exceeded the limit value of 25 milligrams per litre applicable to groundwater at 69% of the sites and in 26% of the samples (Fig. 5.2.1). As mixing and denitrification during seepage dilute nitrate concentrations, the maximum values in the groundwater were only above the limit at approximately 2% of the forest monitoring sites of the National Groundwater Monitoring (NAQUA) programme (FOEN 2023b). The average nitrate concentration was 4 to 8 milligrams per litre (FOEN 2019b, FOEN 2023b).

There is a clear correlation between high nitrogen deposition from the air and the nitrate concentrations in seepage water (Waldner et al. 2019, Braun et al. 2020A). Both nitrogen deposition and nitrate concentrations in seepage water in forest areas declined slightly in the early 2000s, since when they have remained at a high level (Fig. 5.2.1; Thimonier et al. 2019). Soil properties, tree species composition and forest management type also influence the extent of nitrate leaching (Waldner et al. 2019, Braun et al. 2020a). For example, experiments in the USA and in European countries (Hegg et al. 2004) as well as observations in Switzerland (Schleppi et al. 2017, Braun et al. 2020a) have shown that logging or a severe disturbance of the tree population (e.g. due to windthrow or bark beetle infestation) can trigger a sharp increase in nitrate leaching for up to five years after the event.

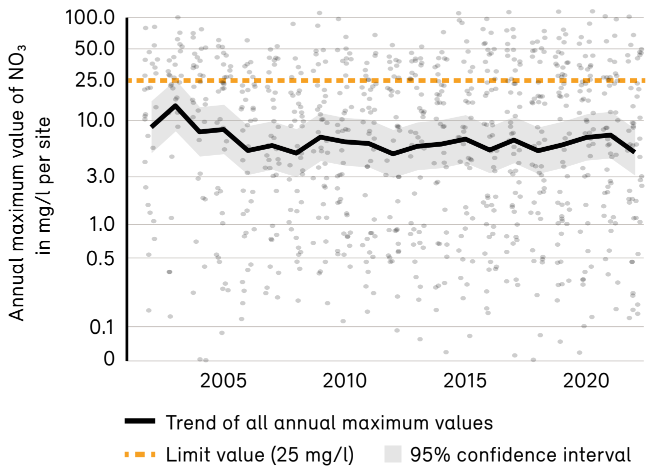
Improving drinking water quality

The legal protection of forest in terms of its spatial extent and as a close-to-nature community also includes drinking water protection. Forest managers can take voluntary measures to improve the quality of drinking water or reduce the risk of contamination, for example by increasing the proportion of broadleaves in forest stands with unnaturally high levels of conifers and using only biodegradable fuels and lubricants in forestry operations (Blattert et al. 2012). Some forest owners have entered into contractual agreements with water supply companies concerning the provision and financing of such services (Godi 2020).

Climate change poses new challenges for drinking water protection in forest areas as it triggers more disturbances that increase nitrate leaching on land with high nitrogen deposition. Results from the WDB show that beeches in these areas were less able to withstand dry periods in summer (Braun et al. 2021), spruces were more likely to die (Tresch et al. 2023) and both species were more susceptible to storms (Braun et al. 2023b). Reduced nitrogen deposition from the air and forest management that boosts tree populations' resistance and resilience to disturbances and that helps forests adapt to the changing climate can ensure low nitrate concentrations in seepage water and thus also in drinking water from forest areas.

Figure 5.2.1

Annual maxima from the monthly measurements of nitrate concentration in seepage water on 45 WDB sites and eight LWF sites from 2002 to 2022. The nitrate concentration considered is that of the deepest soil water measurement at each site.



Source: Simon Tresch (IAP), Katrin Meusburger (WSL)

6

Social Economy

Hiking trails on the Uetliberg (ZH): Forests, especially those near towns and cities, offer space for recreation and well-being.

Photo: Roland Olschewski

Hohens
einstrasse
Feldenmooshau 30 min
Altstetten 55 min
Schlieren 1 h 35 min
Urdorf 1 h 35 min
etliberg 30 min
etliberg Uto Kulm 40 min
Albisrieden 45 min
47

6 Social Economy

Roland Olschewski, Clémence Dirac Ramohavelo

The forestry and wood industries provide a wide range of services for the Swiss economy and public. Equally, people and the economy greatly influence the use of forests and wood resources. The growing demands placed by the population on private and public forest owners and on forest multifunctionality have both advantages and disadvantages. On the one hand, additional sources of income become available, for example through carbon storage certificates. On the other hand, there may be trade-offs if multiple forest ecosystem services need to be provided simultaneously, e.g. raw wood production, recreational opportunities and protection against natural hazards. A further complicating factor is climate change, the effects of which require investments in forest adaptation. The increasing use of natural resources as part of the energy transition is also a challenge for forest management. Better cross-sector coordination and integration of policy is required to address this situation.

6.1 Forest ownership

Matthias Biolley, Claire-Lise Suter Thalmann

- Some 71% of the forest area is in public ownership, with 3,400 owners holding an average of 265 hectares. The remaining 29% is held by over 248,000 private individuals, each owning an average of 1.5 hectares of forest.
- For private forest owners, non-material values are often just as important as the material benefits of forest management, if not more so.
- Restructuring means that the number of forest enterprises will tend to decrease, with the average size of the remaining enterprises increasing.

Forest owners

Swiss forests are freely accessible to everyone by law. People are therefore often unaware that every forest is owned by somebody. The total forest area in 2021 was split between 248,000 private and public owners, of whom 99% were private forest owners (PrFOs) (Fig. 6.1.1; FSO 2022a). PrFOs mainly own small forests of less than 50 hectares. Indeed, the average holding is just 1.5 hectares.

The remaining 3,400 or so public forest owners (PuFOs) own 71% of the forest area and are responsible for 64% of wood use. Their holdings are significantly larger than those of PrFOs, averaging 265 hectares. However, the ownership situation varies from canton to canton. In the canton of Appenzell Ausserrhoden, 77% of forest is privately owned, compared with just 9% in the canton of Valais.

In Switzerland as a whole, 42% of publicly owned forest belongs to political communes and 41% to citizens' communes (Bürgergemeinden). These two types of structure hold almost 750,000 hectares of forest, 59% of Switzerland's total forest area (FSO 2022a). Just over 5% of the area is owned by the Confederation and cantons while just under 7% belongs to other PuFOs. The distribution and number of forest owners have barely changed in the past decade.

Owners' attitudes to their forest

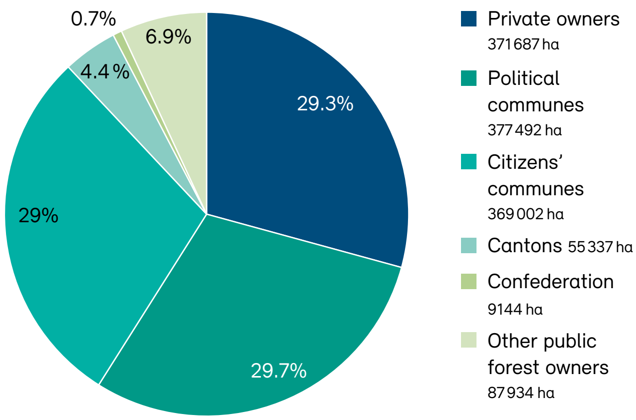
Owners have differing attitudes towards their forest. A 2018 study established a typology of private and public forest owners (Walker and Artho 2018). This found that 35% of PrFOs generally do not use their forest for a particular purpose. Wood harvesting is the focus for 21% of PrFOs. They value a healthy and stable forest that produces wood, and tend to live and work in rural areas. Other groups prioritise forest tending. They can be categorised as nature conservationists (11%) and those who want to contribute to the common good (16%). When it comes to harvesting, these PrFOs focus on energy wood for their own use.

PuFOs' primary objective is a healthy and stable forest (Walker and Artho 2018). Wood production is the main priority for corporations, while services that benefit the public, such as biodiversity or drinking water protection, are more important for political and citizens' communes.

Among PrFOs, 64% managed their forest themselves, while 16% left it unmanaged. In many cases, non-material values were just as important for PrFOs as the material benefits of forest management, if not more so. Among

Figure 6.1.1

Distribution of Switzerland's forest area (in % and hectares) by ownership type, 2021.



Source: FSO 2022a

PuFOs, 55% managed their forest themselves via members of the organisation or their own forest enterprise, while 8% did not manage the forest at all (Walker and Artho 2018).

Structural change in forest enterprises

In 2021, 2,360 forest owners had their forests managed by 656 forest enterprises. The total area managed was around 795,000 hectares, or 63% of the Swiss forest area (FSO 2022a). The term 'forest enterprise' was redefined in 2015 when the Swiss Forestry Statistics were revised. Accordingly, a management unit is considered a forest enterprise if it:

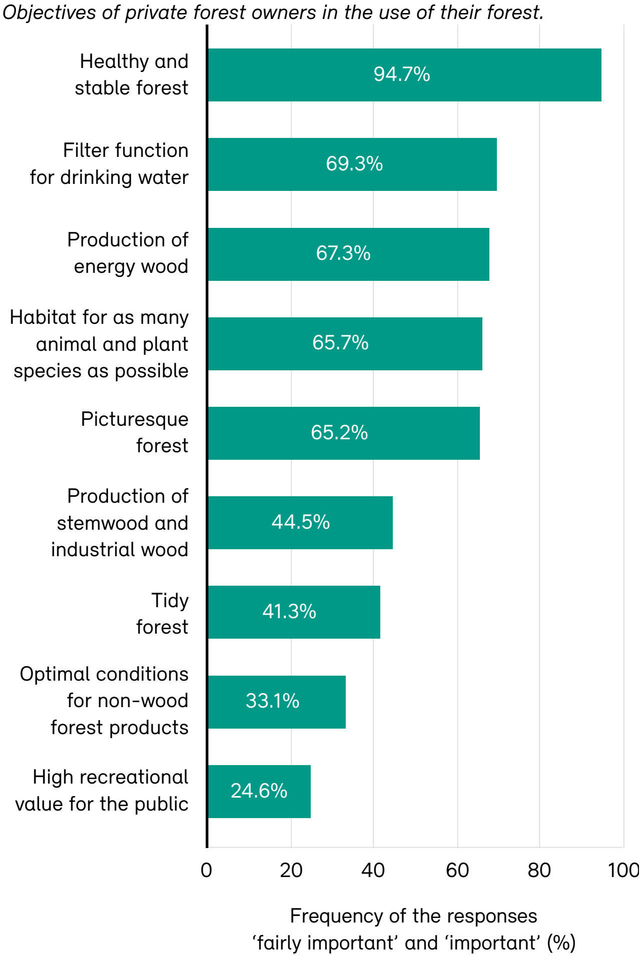
- holds rights of ownership or disposal over the managed forest area for more than one year,
- has a certain minimum productive forest area (Jura ≥ 200ha, Plateau ≥ 150ha, Pre-Alps ≥ 250ha, Alps and southern side of the Alps ≥ 500ha),
- keeps consolidated accounts.

The majority of forests managed by forest enterprises are in public ownership. Forests whose management is not organised by a forest enterprise (small public and private forests) are usually managed by a private forestry service company.

If they are to remain economically viable in the future, forest enterprises will need to organise themselves more efficiently than hitherto and merge into larger management units. The size of Swiss forest enterprises has grown by an average of 8% over the past seven years (FSO 2022a), mostly as a result of mergers between existing enterprises. However, the total area managed by forest enterprises has not increased. The management structures for small forests of less than 50 hectares have barely changed either. However, in view of the need to adapt forests to climate change, it would be advantageous if small forest owners were to organise themselves into larger and more professional operating units or join existing forest enterprises that can implement the silvicultural measures required by changing conditions more expertly and cost-effectively.

Figure 6.1.2

Objectives of private forest owners in the use of their forest.



Source: Walker and Artho 2018

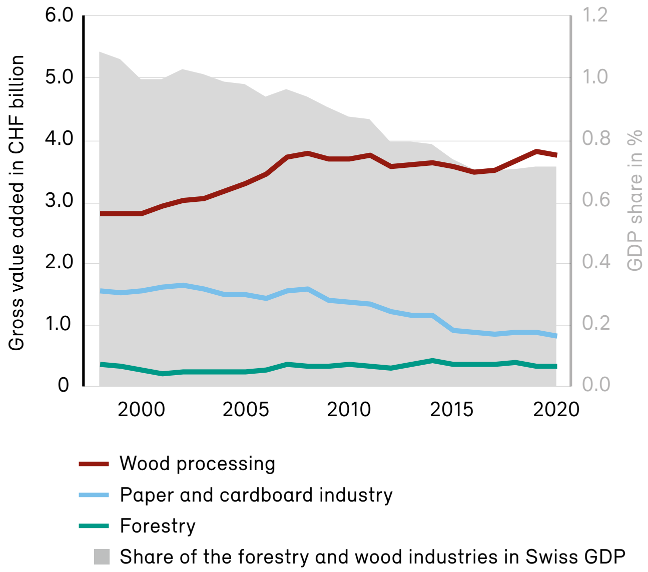
6.2 Economic importance of the forestry and wood industries

Franz Murbach

- The production volume and output of the forestry sector have fluctuated over the past decade. Since 2021, timber prices have risen for the most part, owing to supply problems caused by the pandemic and the additional demand triggered by the war in Ukraine.
- The gross value added of the forestry and wood industries in 2020 was CHF 4.9 billion, equivalent to 0.7% of Switzerland's gross domestic product.
- Forestry's share in cantonal economic output differs from canton to canton, and is determined in particular by the size and topography of the forest area.

Figure 6.2.1

Gross value added of Switzerland's forestry and wood industries, at current prices, and share of Swiss gross domestic product.



Sources: FSO 2022b, FSO 2022c

Economic developments

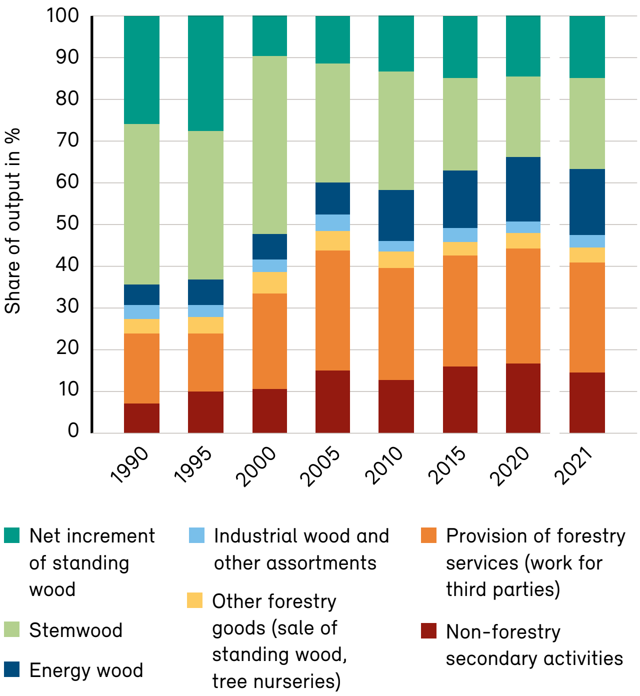
The Swiss forestry and wood industries produced goods and services worth CHF 12.7 billion in 2020, generating gross value added of CHF 4.9 billion, equivalent to 0.7% of Switzerland's gross domestic product (FSO 2022b). Value added in the wood processing industry rose steadily between 1998 and 2008, since when it has fluctuated between CHF 3.5 billion and CHF 3.8 billion. The paper and cardboard industry contracted sharply until 2015 and has since stagnated (Fig. 6.2.1). Storm Lothar in late 1999 led to excess supply on the wood market. Since then, the gross value added of the forestry sector has increased, totalling around CHF 0.4 billion per year over the past decade and exceeding this value in 2014, 2018 and 2021. From 2014 to 2020, round stack wood prices fell by 12%, while prices for energy wood rose by 4%. From 2020 to 2022, prices for raw wood and sawn timber also rose sharply, up by 20% and 27% respectively (FSO 2023). The post-pandemic economic recovery and the war in Ukraine have had a significant impact on the wood markets. The timely supply of commercial timber and energy wood is a challenge for the entire wood industry, as the characteristics of wood as a resource mean that it is not possible to respond to a short-term increase in demand on a just-in-time basis. Months or even years can elapse between harvesting, sawing, drying and processing.

Diversification and specialisation of forestry production

The composition of Swiss forestry output has changed since 1990, reflecting a radical transformation (Fig. 6.2.2). Non-forestry ancillary activities have increased, suggesting a diversification of forestry units, in the area of wood processing for example. Services provided by specialised companies for forest owners (such as logging) have become increasingly important, especially since Storm Lothar. The share of stemwood in production has fallen sharply in the past decade, while energy wood has gained in importance (section 3.2, section 6.7). The net increase in the value of standing growing stock in economically viable forests is influenced in particular by differing trends in raw timber prices and harvesting costs (excluding protected forests and uneconomical forests in which the harvesting costs would exceed any proceeds from timber sales). These changes affect the value of the standing

Figure 6.2.2

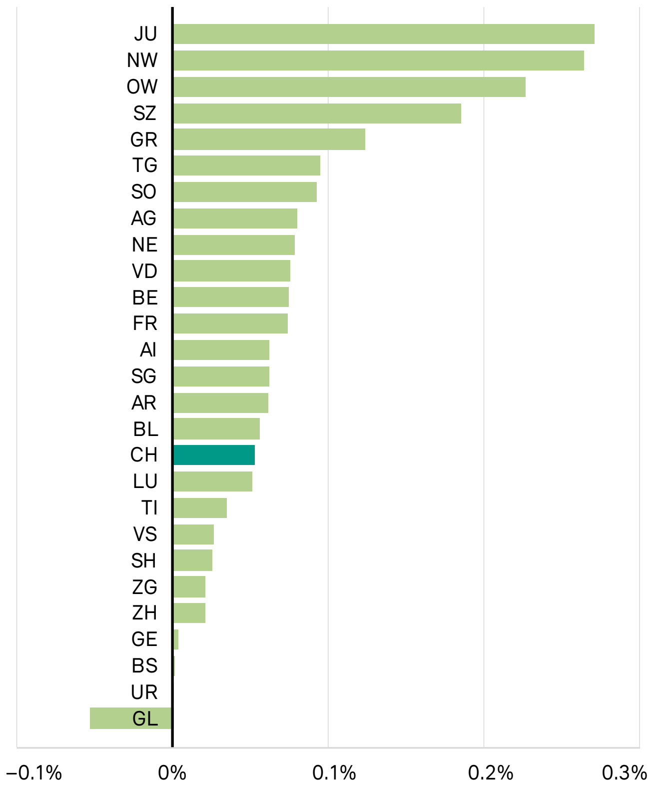
Share of forestry output, at current prices.



Source: FSO 2022c

Figure 6.2.3

Forestry's gross value added as a proportion of cantonal economic output, at current prices, 2020.



Sources: FSO 2022c, FSO 2022d

growing stock (section 1.2). The volume of growing stock (economical, uneconomical and protected stock) in Swiss forests increased from 380 million cubic metres in 1990 to almost 440 million cubic metres in 2021 (FSO 2022c). By contrast, the value of standing growing stock fell sharply from almost CHF 20 billion to less than CHF 7 billion during this period, mainly owing to the continuous rise in harvesting costs over this time. With timber prices fluctuating over the years, these costs have resulted in a lower overall valuation.

Economic importance of forestry

Forestry's share in cantonal economic output differs from canton to canton (Fig. 6.2.3). In the canton of Jura, the forestry sector accounted for just under 0.3% of gross value added in 2020, while the share was significantly lower in predominantly urban cantons such as Basel-Stadt or Geneva. The low values in the cantons of Glarus and Uri show that the value of the wood produced does not cover the input costs every year, as the Alpine topography makes forestry and logging very costly. However, a general point to bear in mind is that, as well as the statistically recorded wood production, forests provide numerous unrecorded ecosystem services 'free of charge' (section 3.4). The national accounts therefore do not fully reflect the actual socio-economic importance of forestry.

6.3 Economic situation of forest enterprises

Matthias Biolley, Janine Schweier

- Overall, the economic situation of forest enterprises has hardly changed over the past decade.
- There are enterprises in all forest zones that manage the forest at a profit. On average, however, the financial result is negative.
- Adapting forests to climate change and the increasing frequency of extreme climatic events pose a major challenge for forest enterprises. The key levers for sustainable operations are cost reduction and valorisation of ecosystem services.

Costs, revenues and financial results

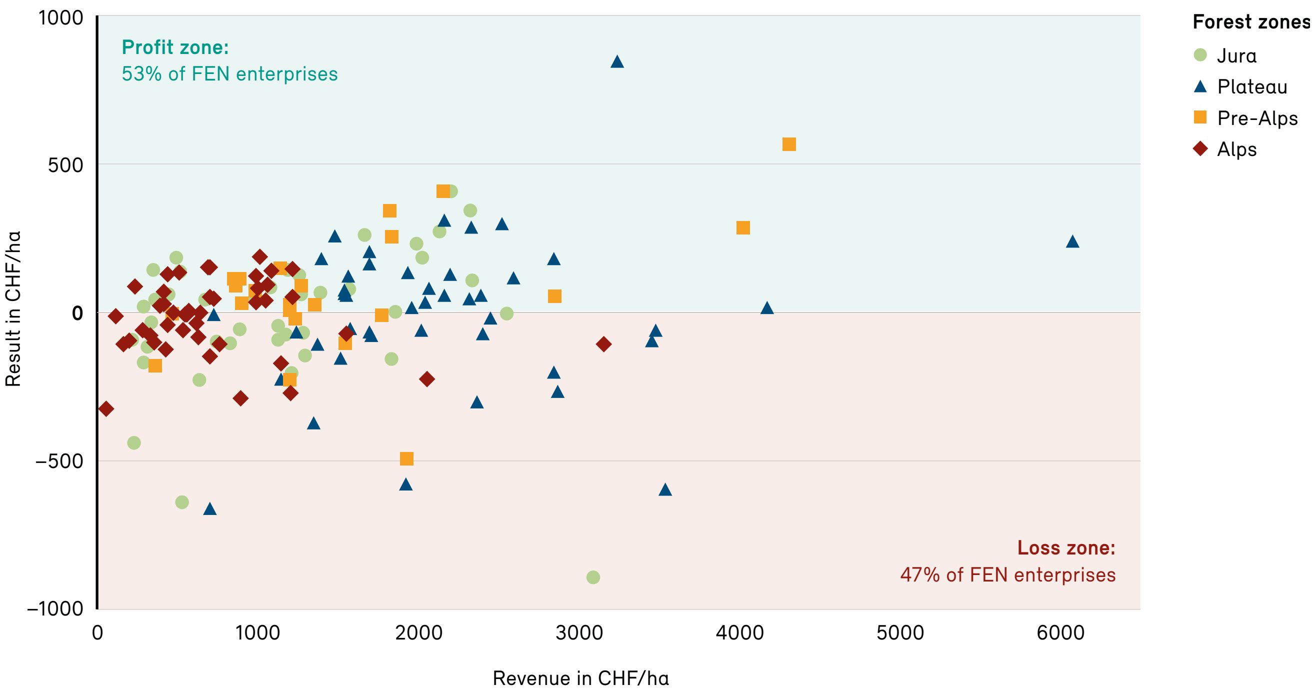
Swiss forest enterprises have recently seen a slight improvement in their overall financial performance, largely due to the significant rise in timber prices since 2021. Overall, the economic situation of forest enterprises has hardly changed over the past decade. Enterprises are faced with high costs on the one hand and generally low timber revenues on the other (FOEN 2022c).

According to the Swiss Forestry Statistics, the costs of forest enterprises in Switzerland totalled around CHF 590 million in 2021 while revenues amounted to around CHF 583.5 million, meaning a loss of CHF 6.5 million. Despite the negative result, this was a significant improvement. Between 2010 and 2020, the average annual loss was more than CHF 41 million (FSO 2022a).

The 2021 key figures from the Swiss Forest Enterprise Network (FEN) – a sample of 160 selected forest enterprises – show how varied the financial situation of forest enterprises is (Bürgi et al. 2021). The highest forest management costs in Swiss francs per solid cubic metre of wood (CHF/scm) were in the Alps, at CHF 184/scm, and

Figure 6.3.1

Scatter plot of the operating results of forest enterprises in the Forest Enterprise Network by forest zone, 2021.



Source: Bürgi et al. 2021

the lowest in the Jura, at CHF 89/scm. Revenues per solid cubic metre, including public funding, were also highest in the Alps (CHF 165/scm) and lowest in the Jura (CHF 91/scm).

In terms of results per hectare, the management costs and revenues were highest on the Plateau (CHF 1,031/ha and CHF 942/ha respectively). The lowest costs and revenues were in the Alps (CHF 366/ha and CHF 328/ha respectively). This can be explained by the fact that the intensity of use (in scm/ha) is significantly lower in the mountains than on the Plateau. The average result from forest management in the Jura was CHF 11/ha, compared with CHF – 89/ha on the Plateau. In the Pre-Alps and the Alps, the results were CHF – 24/ha and CHF – 38/ha respectively.

The services provided by forest enterprises, such as tree surgery, guided tours and looking after third-party woodland, had a positive impact on the operating results (CHF + 12/ha). Conversely, the sale of material goods (woodchips, wood processing, Christmas trees, etc.) had a negative impact (CHF – 7/ha). The average financial result for all operations (including forest management, material goods production and services) was CHF – 29/ha.

The results of FEN forest enterprises varied widely even within the same forest zone (Fig. 6.3.1). This indicates that financial results are not solely determined by natural factors such as topography.

Explanatory factors and revenue items

The high costs are mainly down to staff and machinery, which in many enterprises are not optimally tailored to the operating conditions. Enterprises on the Plateau have the highest staff density per hectare of managed forest, while those in the Alps have the lowest, partly due to the lower intensity of use in the mountains. As a rule, the proportion of work carried out in house is also higher for an enterprise with more employees and machinery, as the enterprise usually endeavours to make full use of its own resources (Bürgi and Pauli 2016). Specifically when harvesting wood, this leads to the use of suboptimal and therefore more expensive harvesting methods.

The biggest revenue item for FEN forest enterprises is forest management, at 51%. This is divided into timber revenues (26%), public funding and remuneration for protective forest management (23%), and other revenues from forest management (2%). Other sources of revenue for forest enterprises are services (35%) and the sale of material goods (14%) (Bürgi et al. 2021). In many places, enterprises are still largely unable to valorise ecosystem services that are not explicitly commissioned by the public authorities, such as recreational services.

Although the economic situation is generally difficult, there are financially successful enterprises in all forest zones, pursuing a variety of different strategies. Of these successful forest enterprises, 14% focus their economic activities almost exclusively on forest management. The majority of forest enterprises (86%) provide services on a medium or large scale and produce material goods, alongside forest management (Bürgi et al. 2021).

Strategies for the future

Reducing the share of work done in house and having a clear strategy could help many forest enterprises to make better use of modern information and communication technologies, thereby potentially boosting productivity in forest management (Bürgi and Pauli 2016). Having the right staff and machinery for the area managed is also essential. This, combined with the increased but flexible use of private forestry service companies and more cost-efficient machinery, would help to cut costs. Equally important is the proper valorisation of forest ecosystem services that are not currently remunerated, such as recreational services (section 3.4). Optimising the cost structure is also a top priority, particularly as many forest enterprises will need to make major investments to adapt their forests to the effects of climate change.

6.4 Federal support for forestry

Tobias Schulz, Tamaki Ohmura, Jacqueline Bütikofer, Michael Husistein

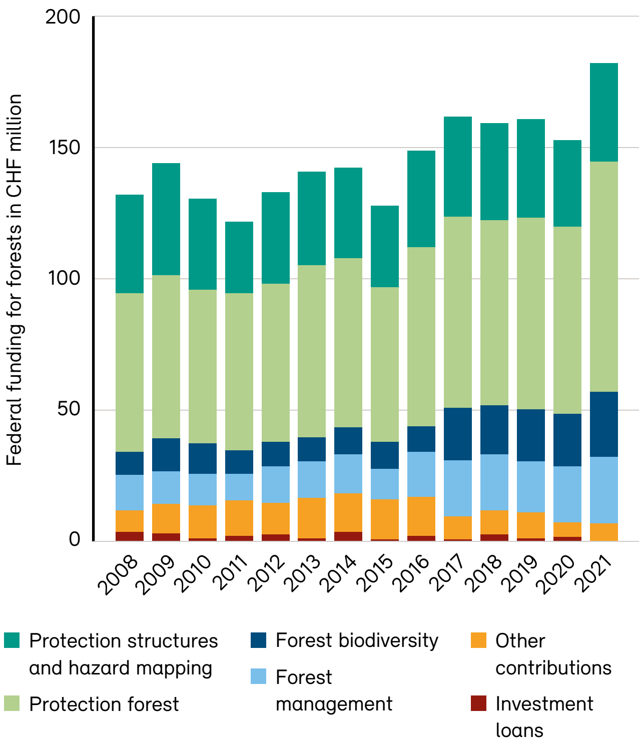
- Since 2016, federal funding has been geared towards climate change adaptation, including greater support for forest tending measures in areas not classed as protective forest.
- Federal funding for forest tending measures were raised on an exceptional basis in the period 2021–24, owing to stronger and more diverse climate impacts, particularly as a result of drought years.
- The Integral forest and wood strategy 2050 will enable better coordination of forest policy and wood resource policy, and places federal funding for forests on a new political footing.

Historical development of forest support policy

In contrast to the very stable core elements of forest policy, such as the forest conservation requirement, forest support policy has developed dynamically. Initially, it was limited to afforestation, building of barrier structures and forestry infrastructure such as forest roads. Funding for the management of mountain forests followed in the mid-1980s, and shortly afterwards, in the context of the debate on forest dieback, support was extended to all forests in Switzerland (Zimmermann 2015). As a result, federal funding has risen considerably, sometimes exceeding CHF 300 million annually in the years following the devastating storm events Vivian (1990) and Lothar (1999).

Figure 6.4.1

Federal funding for forestry since 2008.



Source: FOEN 2009–2022

Federal funding from 2008 to 2015

The 'new system of fiscal equalisation and division of tasks between the Confederation and the cantons' (NFE) in 2008 heralded a move from cost-oriented to performance-oriented allocation of federal funding for forest management. In the first NFE period (2008–11), federal funding averaged CHF 130 million per year (Fig. 6.4.1).

Until 2019, there were three forest support programmes, 'Protective forest', 'Forest biodiversity' and 'Forest management', as well as 'Other funding'. The latter were used for measures under the Wood Resource Policy, for the Forests and Climate Change research programme and for forest protection measures. Federal funding for the forestry sector also includes investment loans to improve operating structures and working methods. These were particularly important in coping with the effects of Storm Lothar (Zimmermann 2015). Alongside assistance for forests, protection against natural hazards such as landslides, rockfalls and avalanches is supported via the 'Protection structures and hazard mapping' programme.

Implementing the objectives set out in the respective programmes is a joint task under the NFE programme agreements and is financed roughly equally by the Confederation and the cantons. In this way, nationally defined objectives can be adapted to the cantons' specific circumstances during implementation. The cantons thus set different priorities for the programmes and the programme objectives in certain areas.

In the first two NFE periods (2008–11 and 2012–15), annual funding was roughly equal (Fig. 6.4.1). Expenditure on the 'Protective forest' and 'Protection structures and hazard mapping' programmes accounted for around two thirds of total forest funding, while the 'Forest biodiversity' and 'Forest management' programmes received around 10% each.

Adaptation of forests to climate change and forest biodiversity from 2016

The revised Forest Act came into force in January 2017. At the start of the NFE period 2016–19, this resulted in some programmes receiving increased funding for measures to adapt forests to climate change. Funding for protective forests ('Protective forest tending') and support for forestry ('Forest regeneration and young forest treatment') were each increased by CHF 10 million per year from 2017 onwards (BBl 2014 4909, here 4945). The change to the law also introduced urgently needed support for forest protection measures and forest transport infrastructure in forests not classed as protective forests (BBl 2014 4909, here 4911).

In addition, greater weight was given to forest biodiversity. This was manifested in guidance on promoting forest biodiversity and a CHF 10 million increase in federal funding (Fig. 6.4.1), the latter being approved for the period 2017–23 in the Action Plan for the Swiss Biodiversity Strategy (BAFU 2013).

Extraordinary increase in federal funding from 2021

The report 'Forest Policy: objectives and measures 2021–2024' was published at the start of the NFE programme agreements for 2020–24, reflecting a fundamental commitment to the continuation of the Forest Policy 2020 (BAFU 2021c). This action plan reaffirmed the previous objectives while aiming for better coordination between tasks assigned to the Confederation, cantons and other stakeholders. It also sought to introduce greater flexibility in the implementation of measures and to improve interaction between the Federal Office for the Environment (FOEN) and the cantons. In terms of content, the action plan set new priorities for promoting wood as a material and for adapting forests to climate change. In this context, the Confederation combined the NFE programmes 'Protective forest', 'Forest biodiversity' and 'Forest management' into a 'Forest' programme agreement (with the previous categories as sub-programmes), with effect from 2020. This offers greater flexibility, which is necessary as the need for federal funding varies greatly from canton to canton.

Damage from a combination of extreme events such as drought and windthrow has been worsening since 2018, even affecting stands that were not previously considered to be particularly at risk (section 2.5). This prompted a series of motions in Parliament calling for a short-term increase in funding to deal with the damage (Fässler motion 20.3745) and a longer-term strategic reorientation to adapt forest management to climate change (Hêche/Engler motion 19.4177 and Vara postulate 20.3750). As a result, federal funding for the NFE 'Forest' programme agreement and for supplementary measures (forest tending to enhance stability, safety felling and climate-adapted forest regeneration) was increased by CHF 25 million per year for four years (2021–24). Medium-term measures to tackle the challenges of climate change are set out in the report 'Anpassung des Waldes an den Klimawandel' ('Adapting forests to climate change') (Swiss Federal Council 2022).

The rise in federal funding since 2008 shows that politicians and the public are willing to support the forestry industry in its efforts to conserve forests and the diverse services they provide under the more challenging conditions arising from climate change. The 'Integral forest and wood strategy 2050' will enable better coordination of forest policy and wood resource policy, and place federal contributions for forests on a new policy footing.

6.5 Employees in the forestry and wood industries

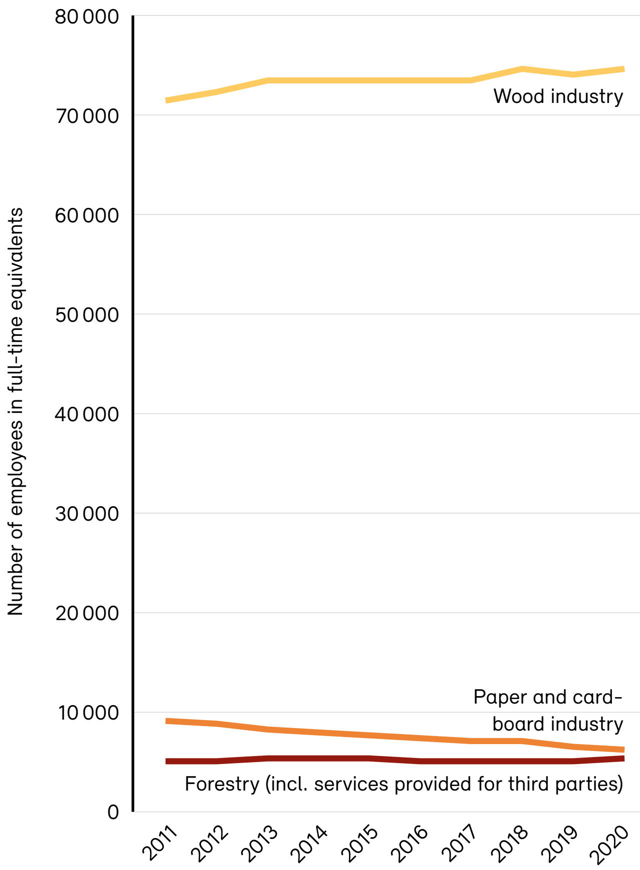
Gerda Jimmy, Achim Schafer

- The number of employees in the forestry and wood industries remained constant from 2011 to 2020. In the forestry sector, it fell by 17% until 2018 and then rose again by 7%.
- A total of around 96,000 people were employed in the forestry and wood industries in 2020, of which 2,900 worked in forestry and 3,300 in forestry service companies.
- Looking ahead, measures to combat the shortage of skilled labour are expected to be a major priority for the forestry and wood industry.

Professions in the forestry and wood industries
The forestry and wood industries comprise the forestry and wood sectors (including wood processing) and the paper and cardboard industry (including the pulp industry). Basic vocational education and training (VET) resulting in a Federal VET Diploma is available for professions including forestry worker, wood industry specialist, carpenter, joiner and paper technologist. In all sectors, various VET further training qualifications are also offered, either for specialisation (forestry machine operator or timber construction forewoman/foreman) or for management positions (forester or wood industry production manager).

Number of employees in the forestry and wood industries
From 2011 to 2020, the total number of people employed in the forestry and wood industries fluctuated between 96,300 and 97,600, with around 86,000 to 87,000 full-time equivalents (FTEs) (FSO 2022e). Employment in the wood industry (primarily craft businesses such as carpentry and joinery enterprises and sawmills) increased steadily by a total of 4% until 2020 (Fig. 6.5.1). By contrast, the paper and cardboard industry saw its workforce decline by a third to 6,700 FTEs in 2020 (FSO 2022e). Employment in forestry fell by almost 10% between 2011 and 2020, with the largest decline of 17% between 2011 and 2018, since when there have been signs of a recovery. Conversely, the number of employees in companies providing services for the forestry industry climbed by 25% between 2011 and 2020 (FSO 2022e).

Figure 6.5.1
Employment in the forestry and wood industries from 2011 to 2020, broken down into three sectors.



Source: FSO 2022e

Number of employees in forestry
In 2020, the forestry sector employed just under 2,900 people, equivalent to 2,500 FTEs or just under 2 FTEs per 1,000 hectares of forest. Their tasks include forest tending, wood harvesting and forest nursery work. They were supported by some 3,300 forestry and logging service providers, equating to around 2,800 FTEs or 2.2 FTEs per 1,000 hectares of forest (FSO 2022e). The number of employees per unit of area varies greatly between forest zones, reflecting the differing intensity of wood use between regions (Fig. 6.5.2). The larger number of staff deployed on

the Plateau is particularly striking (section 6.3). In 2020, 8.75 solid cubic metres of wood per hectare (scm/ha) were harvested in the Plateau forest zone, more than twice the national average (3.77 scm/ha) (FOEN 2021d).

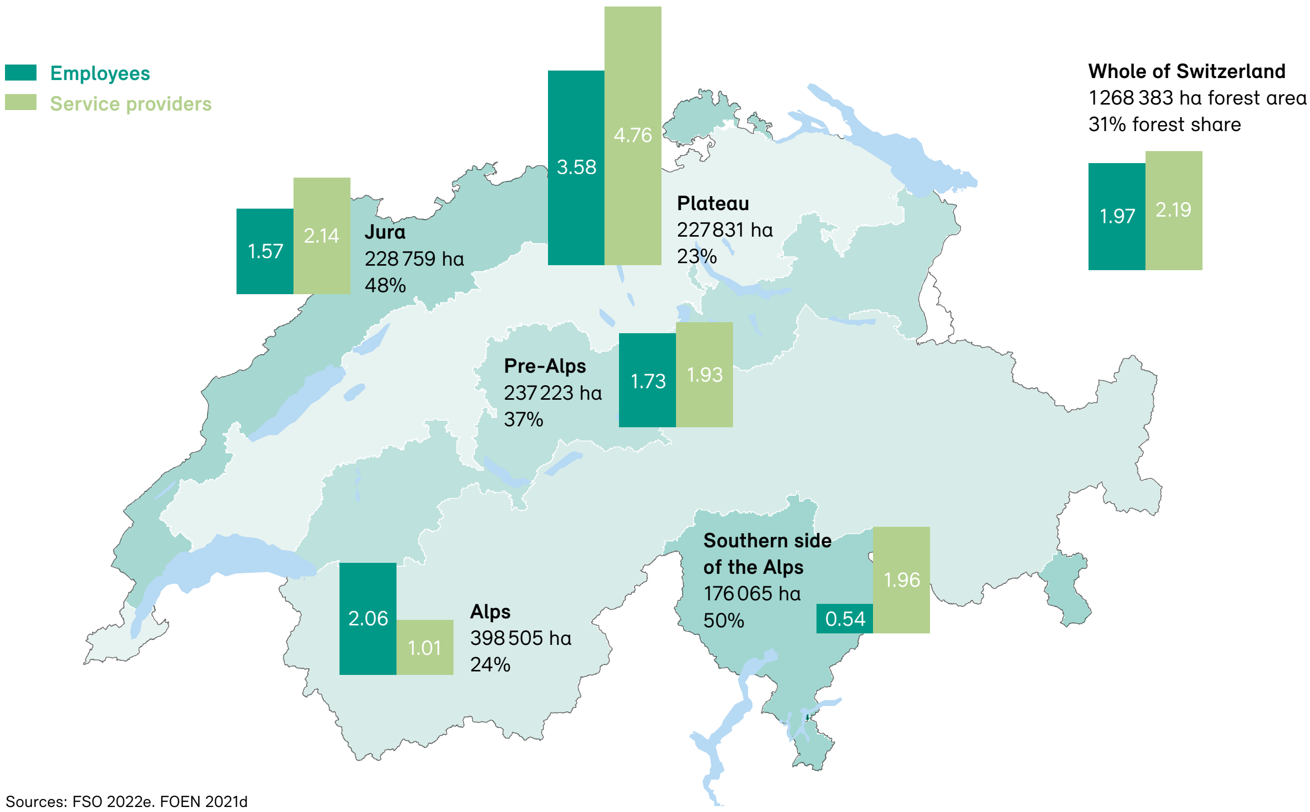
Future prospects in the forestry profession

Despite high levels of interest and a sufficient number of graduates from forestry courses, the forestry sector, like others, faces a shortage of skilled labour. Well-trained specialists have become increasingly scarce in the past decade and the situation appears to be worsening. In 2022, the Swiss Association of Forestry Workers' Organisations commissioned an analysis to address the shortage of skilled labour. It found that long-term staff retention is one of the greatest challenges and proposed improvements, particularly in the area of working and employment conditions, such as flexible working time models and varied work schedules (Landolt et al. 2023).

Those working in the wood industries also report problems in recruiting sufficient skilled staff. The timber industry, among others, has therefore launched an information campaign for schoolchildren about career opportunities within the sector.

Figure 6.5.2

Number of employees in the forestry sector per 1,000ha of forest area in the five production regions and in Switzerland as a whole (with total forest area in ha and proportion of forest in each zone), 2020.



Sources: FSO 2022e. FOEN 2021d

6.6 Health and safety

Gerda Jimmy, Janine Schweier

- The number of occupational accidents in forests fell slightly between 2012 and 2021.
- As the risk of accidents during forestry work is high, there are various measures to support the health and safety of forestry workers.
- Preventive measures in occupational health and safety must continue at a high level, also taking into account the effects of climate change. New technologies could support these endeavours.

Preventive measures in forestry

Forestry work is physically demanding and routinely involves potentially dangerous situations. Accident prevention and health promotion measures are implemented in Switzerland to prepare employees for the physical work and to avoid accidents.

In the area of accident prevention, the Swiss National Accident Insurance Fund (Suva) analyses accident reports, raises awareness among companies and employees, and provides information such as factsheets on occupational safety. The 'Ten life-saving rules for forest workers', which have been taught to all trainees on inter-company courses since 2012, are a centrepiece of prevention work in the forestry sector. They include measures such as wearing protective equipment, retreating to a place of safety and providing first aid in the event of an accident. Since 2016, trainees who complete their apprenticeship without any accidents have received an award from Suva.

The FOEN's forestry training unit Codoc also focuses on trainees with its health promotion programme. Since 2018, it has been providing documentation for use at vocational schools, on inter-company courses and in host companies, as a complement to existing training content. The documentation was developed based on experience and existing material. It includes numerous exercises that can be used for on-site warm-ups (Fig. 6.6.1) or for putting together a training programme, as well as a fitness test for sports lessons and a guide containing lesson suggestions for vocational schools. A 'near misses' platform has also been set up, allowing course instructors to discuss hazardous situations with their students and reach conclusions together. In 2022, half-day events on preventive health were introduced at forestry schools in Maienfeld (GR) and Lyss (BE) to raise awareness of this issue among future managers.

Occupational accidents and illnesses

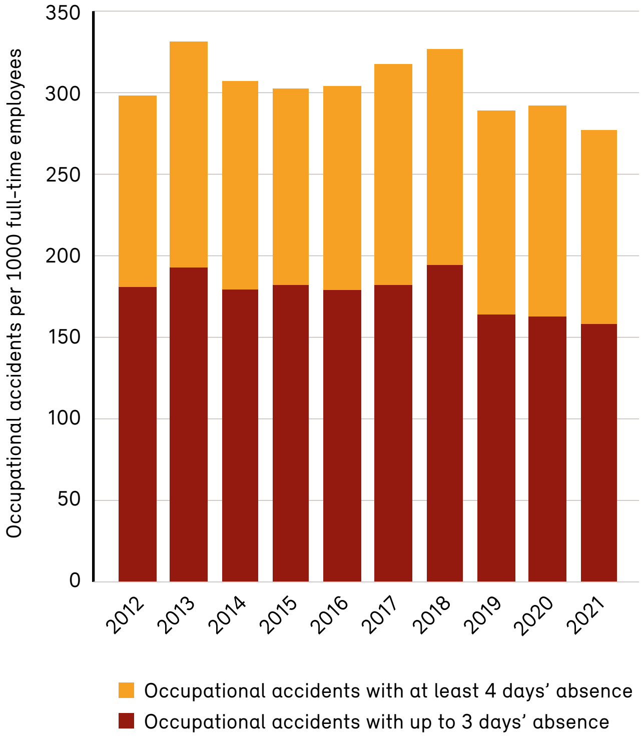
In 2021, 277 occupational accidents per 1,000 full-time employees were recorded among forest enterprises and forestry service entrepreneurs (Suva 2022; Fig. 6.6.2). This was the lowest figure since 2012. Of these, 119 or 43% resulted in more than three days' absence from work. This figure is three times higher than the average for all sectors insured by Suva (40 cases per 1,000 full-time employees). While accidents involving longer absences fell from 2019, there was little change in those involving shorter absences. Forestry work remains a high-risk activity, with 32 fatalities recorded from 2012 to 2021, including six in 2012 alone and between one and four in each of the following years (Suva 2022).

Figure 6.6.1

Inter-company course at Le Mont-sur-Lausanne (VD). Balance and warm-up exercises help to prevent accidents such as those caused by falls. Photo: Gerda Jimmy

Figure 6.6.2

Occupational accidents among forest enterprises and forestry service entrepreneurs per 1,000 full-time employees from 2012 to 2021.



Source: Suva 2022

When it comes to occupational illnesses, the trend appears worrying at first sight as the statistics show a continuous rise in newly registered occupational illnesses between 2012 and 2021: from 16 to 28 cases, or from 3.0 to 4.7 cases per 1,000 full-time employees (Suva 2022). However, a more in-depth analysis reveals a sharp decline in musculoskeletal disorders (Wettmann 2022). The real driver of the increase is hearing loss, which often manifests itself only decades after exposure. But since there has now been a whole generation of forest workers who wear hearing protection as a matter of course, cases of hearing loss are also likely to decline in the future (U. Limacher, Suva, personal communication, 28.2.2023).

Forest work in the agricultural sector

The measures described above relate to work done by forest enterprises and forestry service entrepreneurs. However, a lot of forest work is also done by private individuals, especially in the agricultural sector. These workers also receive support with occupational safety. After Storm Lothar in late 1999, when several people were killed in accidents during clearing work, the Confederation launched a campaign to improve the occupational safety of forest workers without forestry training. This included a raft of measures such as promoting and financially supporting occupational safety courses for untrained forest workers, providing more information about the potential dangers of forest work in an agricultural context, and a statutory obligation to provide proof of training for people who carry out forest work under contract. Efforts to improve occupational safety need to be continued, as evidenced by the statistics on fatalities among agricultural workers carrying out work in forests. Between 2013 and 2022, 51 such cases were registered, 17% of all recorded fatal accidents in the agricultural sector (BUL 2023).

The changes taking place in forests as a result of climate change also need to be considered in relation to occupational safety. The training course run by the Swiss forest owners' association WaldSchweiz on the safe felling of deadwood trees is very popular, for example. There are also new technologies that can digitally simulate accident situations in a virtual environment.

6.7 Use of wood as a material and for energy

Achim Schafer, Claire-Lise Suter Thalmann, Janine Schweier, Oliver Thees

- Over the past decade, the end use of wood, including imports, has increased to around 11 million cubic metres per year.
- Use of wood as a material is tending to decline compared with its use as an energy source, but still accounted for around 41% in 2021.
- A large proportion of energy wood comes directly from forests. The quantity of such wood has increased by 20% in the past decade. The additional potential of forest energy wood that could be harnessed in the future is around 0.8 million cubic metres or 2.3 terawatt-hours of final energy per year.

From production and harvesting in the forest to the finished product, wood as a raw material passes through various processing stages and trade channels. The duration of the processes and the distances transported vary depending on use. Semi-finished and finished wood products are also imported and exported at all stages. In addition, there are recycling processes that enable wood to be reused as a material. The division into material and energy use is largely decided when wood is sold in the forest. A material flow model, based on calculations of raw material volumes and use, depicts material movements (Fig. 6.7.1).

Material use

In 2021, wood end use totalled 11.2 million cubic metres (million m^3), an increase of 5.1% on the previous year. End use is divided into three main categories: material, energy and other uses. The latter includes agricultural and horticultural uses as well as losses. The proportion of wood used as material fell compared with the proportion used for energy, and stood at approximately 41% of total end use in 2021. Wood products (e.g. sawn timber) accounted for just under two thirds of this, and paper and cardboard products for a little over a third. The proportion of wood used for energy rose slightly, totalling around 56% in 2021. At just under 3%, other uses remained at the previous year's level (FOEN 2022c).

Waste wood and waste paper

Waste wood and waste paper are important sources of wood as a raw material, alongside forest wood and imported wood. Approximately 840,000 tonnes of waste wood are collected in Switzerland annually, of which 250,000 tonnes are exported. Around 36% of waste wood is reused as material, mainly in particleboard production abroad. Some 50,000 tonnes are classed as problematic wood waste because they have been treated with wood preservatives. They are mainly used for energy, with a very small proportion being sent to landfill. Approximately 1.2 million tonnes of waste paper are collected in Switzerland each year. Around two thirds of this is recycled into paper and cardboard. The rest is exported or used to generate heat (FOEN 2022c).

Semi-finished wood products

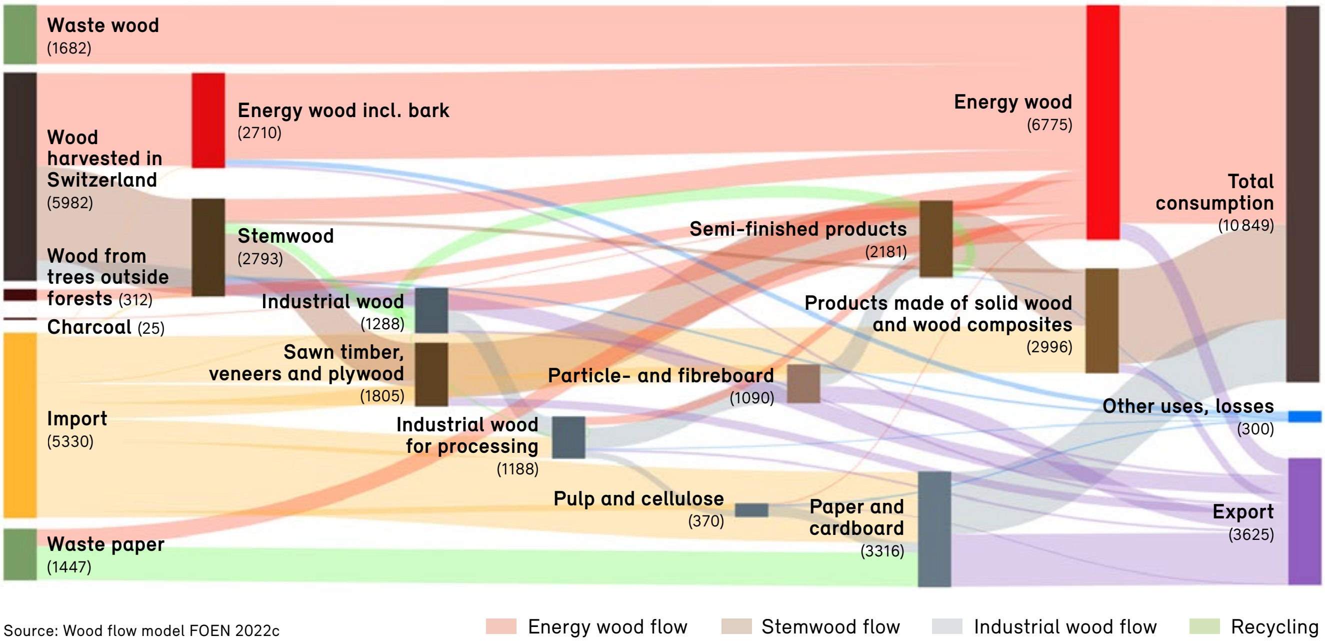
Swiss sawmills produced approximately 1.3 million cubic metres of sawn timber from around 2 million solid cubic metres of round stack wood in 2021. After declining in previous years, cutting increased and was back at 2016 levels in 2021. This rise was due to the trend towards greater use of wood products in construction. Softwood accounted for 96% of sawn timber production, compared with just 4% for hardwood. These values were in line with the average for the previous five years. Particleboard made up the largest proportion of wood composites production, at 450,000m^3 (70%), followed by fibreboard (190,000m^3, 29%) and plywood (7,000m^3, 1%). Mechanical pulp accounted for 94,000 tonnes (FOEN 2022c).

Industrial wood

In 2021, nearly 1.1 million cubic metres of industrial wood was produced, including 544,000m^3 of industrial forest wood and 538,000m^3 of residuals. Just under 110,000m^3 of residuals were also imported. These quantities were used as raw materials in the wood-composites, paper and pulp industries (FOEN 2022c).

Figure 6.7.1

The wood flow model shows the diversity of wood flows (in 1,000m^3) in Switzerland in 2021.



Source: Wood flow model FOEN 2022c

Cascade principle

In the context of wood use, the cascade principle means that wood can be reused multiple times as a material to ensure a better carbon balance. Only at the final stage should forest wood used as a material (stemwood and industrial wood) be the source of residual and waste wood used for energy. This cascade principle is significantly more efficient in terms of energy and resource consumption and fits in with the concept of the circular economy.

Energy use

Wood is a renewable energy source, is considered carbon-neutral in the long term, is produced in a decentralised way, can be stored and is available all year round. It can be used to generate heat, electricity and fuel, with different conversion losses in each case. Energy wood consumption has been steadily rising for over 20 years, and reached around 6 million cubic metres in 2022 (SFOE 2023). According to the Forest Statistics, 2.1 million cubic metres of energy wood was harvested in Swiss forests that year. This represents an increase of around 20% in ten years and a near doubling in 20 years (FOEN 2022c). A significant proportion of the wood used for energy comes from forests. The remainder comes from woodland fragments and landscaping wood, residuals from wood processing (bark, chips, shavings and sawdust) and waste wood that has already been used elsewhere, e.g. in buildings or furniture. Of the hardwood harvested in Switzerland, 50–70% is used as energy wood, compared with just 15–20% of softwood. Energy wood from forests is supplied in the form of logs (40%) and chips (60%). The proportion of chips has been rising for several years. Whether forest wood is used for energy or material purposes depends on wood and energy market price trends and on the production and trading structures in the region concerned.

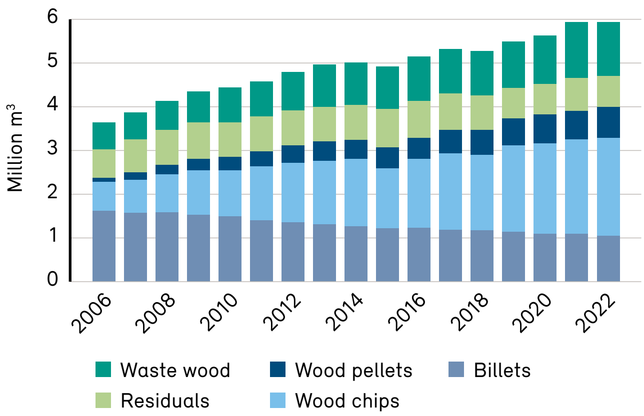
Policy, climate and economic frameworks

The trend towards using wood for energy has been favoured by the policy framework, the effects of global warming on forests and economic changes. At the political level, the decision by the Federal Council and Parliament in 2011 to move towards an energy transition was game-changing, and in 2017 the Swiss electorate approved a new Energy Act providing for the expansion of renewable energies. In 2019, Switzerland's implementation of the Paris Agreement was agreed. These factors resulted in the expansion of support for wood as an energy source, for example through the climate grant for replacing gas and oil heating systems with wood-fired ones.

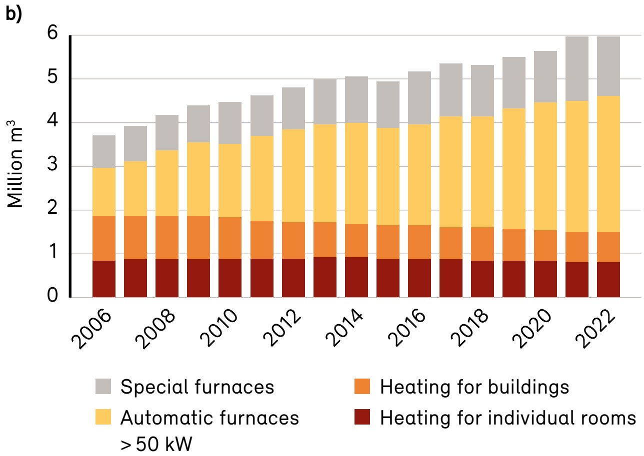
Figure 6.7.2

Energy wood consumption by a) fuel assortment and b) type of furnace/heating, from 2006 to 2022.

a)



b)



Source: SFOE 2023

Global warming favours broadleaved (hardwood) tree species. These now account for almost two thirds of wood used for energy (FOEN 2022c). Meanwhile, other species, notably spruce trees in site-inappropriate stands, are suffering and dying as a result of drought and bark beetle infestation (sections 2.3 and 3.1). This results in more frequent salvage logging and large quantities of damaged wood, some of which is used for energy purposes.

Finally, economic developments such as the relocation of companies that process industrial wood and the decline in domestic furniture production have favoured the use, for energy purposes, of forest wood assortments that would otherwise have been earmarked for higher-value material use, with energy wood prices rising due to the higher demand. Both trends are leading to more intensive use of energy wood and to shifts in assortment, away from industrial wood and stemwood and towards energy wood.

Share in Swiss energy production

The importance of wood energy for domestic energy production has increased significantly in the past decade. In 2022, around 11.2 terawatt-hours (TWh) of useful energy was generated using wood (weather-adjusted). Wood energy is now the second most important renewable energy source in Switzerland after hydropower, accounting for around 5.5% of final energy consumption. In 2022, wood energy accounted for just under 14% of final consumption for heat generation, and just under 1% of gross electricity generation. It played no role in fuel production (FOEN 2022c, SFOE 2023).

The majority of energy wood, around 75%, is burnt in automatic and special furnaces to generate heat (Fig. 6.7.2). The number of furnaces is falling, and stood at 510,000 units in 2022. Manually operated building heating systems are being abandoned in favour of larger automatic systems. This is leading to a reduction in conversion losses, with the efficiency of wood-based heat production reaching 76% in 2022 (excluding waste incineration plants). The increase in efficiency has also resulted in a reduction in emissions of particulate matter, nitrogen oxides, volatile organic compounds (VOCs) and carbon monoxide. The number of single-room heating units remained largely unchanged at 451,500 (90%).

For a long time, up to 97% of energy wood came from Switzerland (Lehner et al. 2013). This has now changed (section 6.8). Imports of wood pellets have doubled in the past decade to around 70,000 tonnes per year, with almost all imported quantities coming from Germany (48%), Austria (30%) and France (19%) (SFOE 2023). The growing number of wood energy plants along the Swiss border has also bolstered demand for imported wood.

Wood Energy Monitoring

In response to the high demand for wood energy, the Federal Office for the Environment (FOEN) launched the Wood Energy Monitoring project in 2022. The aim is to record the actual consumption of energy wood, planned projects and energy wood potential to ensure that only

Table 6.7.1

Energy wood consumption, total potential and additional usable potential in 2022 (discrepancies are due to rounding).

Wood fuel assortments	Total consumption per year		Total potential per year		Additional usable potential per year	
	m m^3	TWh	m m^3	TWh	m m^3	TWh
Forest wood (incl. imports)	3,0	8,2	3,5	9,5	0,5	1,3
Wood from land outside forests	0,3	0,8	0,5	1,2	0,2	0,4
Residuals	0,7	2,2	0,8	2,4	0,1	0,2
Waste wood	1,2	3,2	1,4	3,6	0,1	0,4
Total	**5,3**	**14,4**	**6,1**	**16,7**	**0,8**	**2,3**

Source: Keel and Chrenko 2023

sustainable amounts of energy wood are used in the future. The project is also intended to harmonise and adapt data sources and statistics.

Energy wood potential

Experts have been calculating the energy potential of Swiss biomass for a number of years (Thees et al. 2017). The domestic potential of energy wood is not yet being fully harnessed. Between 2015 and 2022, an average of around 5.5 million cubic metres of wood per year was used to generate energy, compared with a potential of around 6.8 million cubic metres across all wood fuel assortments, equivalent to 18.6TWh of final energy (SFOE 2023). This means that there was additional usable energy wood potential of around 1.3 million cubic metres or 3.6TWh of final energy per year (Keel and Chrenko 2023). For 2022, Table 6.7.1 shows a lower usable potential of 0.8 million cubic metres. This potential could soon be exhausted. An analysis of expected consumption has found that the additional usable potential is already taken up by planned projects and is not sufficient to meet the needs of all projects (Keel and Chrenko 2023). It must therefore be ensured, when planning new wood energy plants, that sufficient energy wood will be available in the long term.

Simulations based on National Forest Inventory (NFI) data allow long-term analyses of energy wood supply to be carried out. These show that energy wood potential depends on the type of forest management and the situation on the wood and energy markets. This potential develops dynamically. One scenario suggests additional usable energy wood potential of 0.7 million cubic metres per year up to 2056, assuming a moderate reduction in the high growing stock in Swiss forests and an emphasis on the material use of wood (Thees et al. 2017). The results confirm the shortage of energy wood identified by the Wood Energy Monitoring project.

Advantages in terms of availability, energy efficiency and carbon balance

Given its limited potential, energy wood has to be used efficiently, taking into account the advantages of wood in terms of availability, energy efficiency and the carbon balance of the entire energy system compared with other renewable energies. In terms of climate impact, the ideal way to use energy wood is producing high-temperature process heat for industry and generating electricity in combined heat and power plants to bridge the winter electricity gap (Nussbaumer 2023, Thees et al. 2023). Technologies for producing chemical energy sources or fuels from wood are not yet fully developed. For heating, energy wood should primarily be used in larger automatic furnaces because these are more efficient and cleaner than small systems. As an energy storage medium, wood can help to balance out fluctuations in energy supply from renewable sources such as wind or solar, thereby supporting the energy transition (Thees et al. 2023).

In keeping with the cascade principle, wood as a resource should wherever possible be used as a material before being burnt for energy. This supports climate change mitigation, promotes resource efficiency and increases value added (Bernath et al. 2013). Achieving such cascade use will require new incentives for material use, which currently receives less support than the use of wood for energy (Odermatt et al. 2023).

6.8 Foreign trade in wood and wood products

Achim Schafer

- Foreign trade in wood and wood products is characterised by an import surplus. This increased sharply by 13.4% in 2021 compared with the previous year, reaching CHF 4.5 billion.
- Despite a rise in exports of raw wood, the volume available domestically climbed by 2.9% to 4.6 million cubic metres in 2021 as more timber was harvested.
- The import surplus of energy wood has steadily increased. In total, around 346,000 tonnes more fuelwood products were imported than exported in 2022.

Table 6.8.1

Total volume and value of foreign trade in wood and wood products from 2017 to 2021.

	Imports		Exports	
	1000 m³ (solid volume)	CHF m	1000 m³ (solid volume)	CHF m
2017	6182	7343	4826	2390
2018	5825	7578	4992	2339
2019	5575	7463	4746	2455
2020	5380	6814	4324	1867
2021	5720	7576	4490	2160

Source: FOEN 2022c

Foreign trade in wood at a glance

Switzerland's most important foreign trading partners for wood and wood products are its neighbours Germany, Austria, Italy and France. Economic developments in specific markets, major exchange rate fluctuations, and transport and logistics costs have a big impact on the balance of trade. Together with exceptional factors such as the availability of windthrown and beetle-infested wood, they can cause major short-term fluctuations in the trade balance.

In 2021, imports of wood and wood products stood at CHF 6.37 billion and exports at CHF 1.83 billion. This equated to 3.2% of Switzerland's total goods imports and 0.7% of its goods exports. The import surplus increased sharply by 13.4% compared with the previous year, resulting in a trade deficit of CHF 4.54 billion.

Across all wood-based products, the volume imported exceeded the volume exported every year from 2017 to 2021 (Table 6.8.1). In terms of value, the difference between imports and exports is even greater, i.e. significantly more higher-value wood, assortments and wood products are imported than exported.

By contrast, the volume of exported raw wood (stemwood, industrial wood and energy wood) increased significantly in 2021 by almost 15% to 0.55 million cubic metres, after a sharp decline the previous year. As the domestic timber harvest rose by 4% to 5 million cubic metres at the same time, the amount of raw wood available domestically increased by 2.9% to 4.55 million cubic metres, while imports remained constant at 0.1 million cubic metres.

Raw wood categories in 2021

Softwood logs

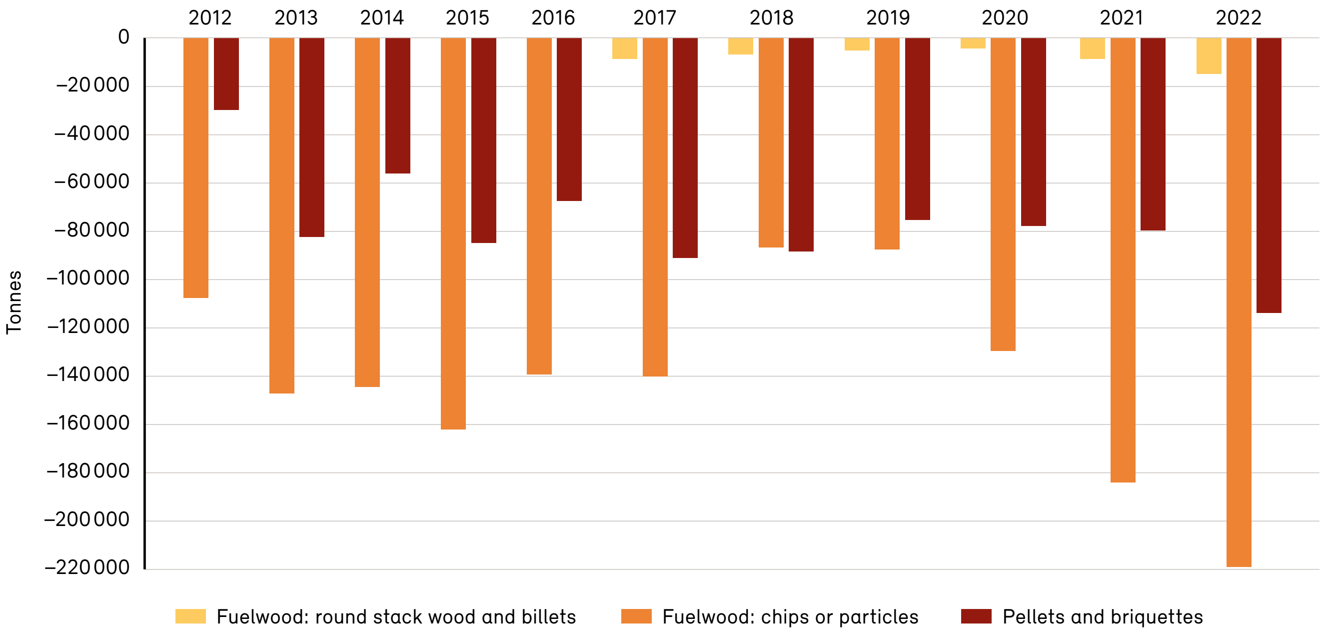
Imports in 2021 fell by 3.6% compared with the previous year to 38,300 cubic metres of solid volume or 34,500 tonnes. Germany was the biggest supplier, accounting for 91.7%. Exports were around ten times higher than imports, rising sharply by 25.3% to 324,600 cubic metres or just under 292,400 tonnes, after declines in the previous two years. Italy was the biggest purchaser, accounting for 51.5%.

Sawn softwood

Imports were up by 2.3% to 299,900 cubic metres. The biggest suppliers in 2021 were Germany (33.7%) and Austria (30.9%). Exports increased by 8.8% to 214,600 cubic metres, the highest level since 2010. As with softwood logs, Italy was again the biggest purchaser (40.9%), followed by France (39.4%). Exports to Asia also rose sharply.

Figure 6.8.1

Foreign trade balance of fuelwood categories in tonnes from 2012 to 2022. The 'round stack wood and billets' category has only been recorded since 2017.



Source: Foreign trade statistics FOCBS

Hardwood logs

Imports were down by 15% on the previous year to 27,400 cubic metres of solid volume. Conversely, exports rose again in 2021 by 12.2% to 149,400 cubic metres, after declining the previous year. Asia remained an important export market with a share of 20.4%, occupying third position after Italy (41.7%) and Germany (21.2%). China alone accounted for 13.8%.

Sawn hardwood

Imports in 2021 were around 45,400 cubic metres, up by 2.9% on the previous year. Germany accounted for 24.8%, followed by Austria (23.1%) and France (20.5%). Exports, which were around half as high as imports, increased by 11.3% to 22,800 cubic metres, with Italy purchasing the most (45.1%). Just 5.0% went to Asia, down from 16.0% the previous year.

Industrial wood and residuals

Imports of industrial softwood rose in 2021 by 32.0% to 19,800 cubic metres, the first increase in three years. However, this figure was well below the average for the past decade. Exports stabilised at 53,900 cubic metres after a sharp decline the previous year, returning to 2016 levels. Both imports and exports of industrial hardwood fell sharply, by 25.4% and 38.0% respectively.

Waste wood

After declining in previous years, imports rose to 1,900 cubic metres in 2021. Exports saw another sharp drop, down by 14.8% to 466,000 cubic metres, but remained a significant part of overall wood and wood product exports, accounting for over 10.4%.

Energy wood

Imports have risen steadily over the past decade, resulting in a negative trade balance in many fuelwood products (Fig. 6.8.1). In 2022, a total of 346,467 tonnes more energy wood was imported than exported, equivalent to around 610,000 solid cubic metres of wood. The negative balance for woodchips and pellets was particularly high.

6.9 Recreation in forests

Tessa Hegetschweiler, Marcel Hunziker, Boris Salak, Jean-Laurent Pfund

- Forests have been and will remain an important recreational space, especially for people living in urban and peri-urban areas. Trees, green spaces and nearby forests make a vital contribution to quality of life in towns and cities.
- People value the forests they visit most often. However, satisfaction with forest visits has fallen over the past decade, while perceived disturbances have increased.
- Recreational use of forests is expected to increase as a result of population growth and urban densification. This poses challenges for the management of peri-urban forests.

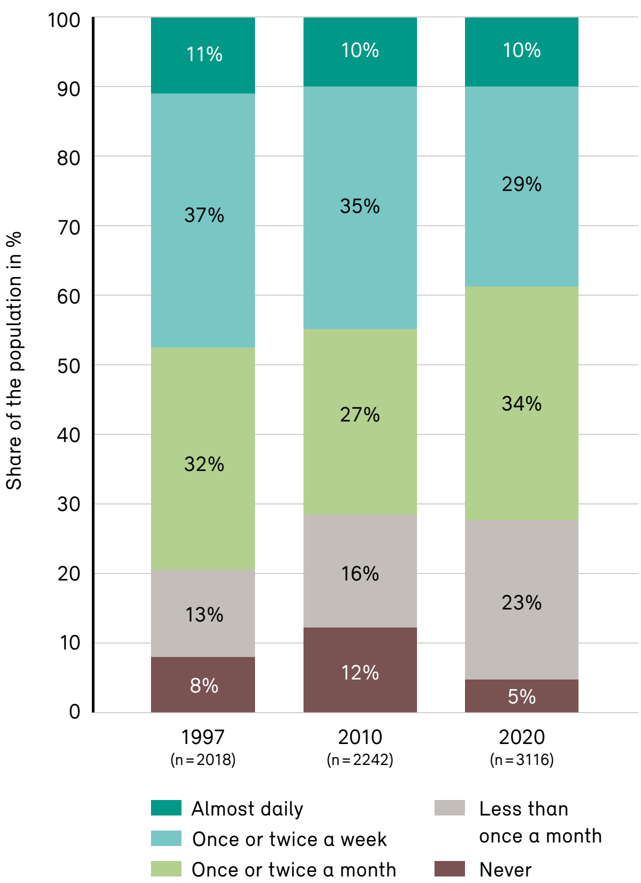
People in the forest

In Switzerland, 80% of the population live within a 15-minute walk of the nearest forest (FOEN/WSL 2022). According to the third Socio-Cultural Forest Monitoring public survey (WaMos3) conducted in 2020, 10% of people go into the forest almost every day (FOEN 2022d). Some 29% visit once or twice a week and 34% once or twice a month (Hegetschweiler et al. 2022). Alongside WaMos, the National Forest Inventory (NFI) also provides information on the use of forests as a leisure and recreational space. Among other things, it asks district foresters about forest functions, priority functions and the intensity, seasonality and type of recreational use within a 100-metre radius of NFI sample plots. The results of NFI4 (2009–17) show that an increasing proportion of the Swiss forest area is being used for leisure and recreational activities and that both the frequency of visits and the number of different activities are growing (Fischer et al. 2020, Hegetschweiler et al. 2021).

Since the second forest monitoring survey in 2010 (WaMos2; FOEN/WSL 2013; Hunziker et al. 2012), there has been a shift in the number of occasional forest visits, with fewer people visiting once or twice a week and more visiting less often (once or twice a month) (Fig. 6.9.1). However, the number of people who never go to the forest has declined over the years. Overall, therefore, the average number of visits per capita has remained constant, and has done for over 40 years. The increase in the frequency of visits

Figure 6.9.1

Frequency of visits to forests according to surveys in 1997 (WaMos1), 2010 (WaMos2) and 2020 (WaMos3).



Source: Hegetschweiler et al. 2022

according to NFI4 can be explained by Switzerland's population growth (FSO 2020). However, the average length of time spent in the forest has steadily decreased since 1997 (WaMos1; SAEFL 1999), falling from 106 minutes (WaMos1) to 90 minutes (WaMos2) to 79 minutes (WaMos3).

Favourite forest activities and motivations for visiting

Over 90% of those surveyed say they 'quite like' or 'really like' the forest they visit most often. Compared with WaMos2, however, the proportion of people who 'really like' the forest has dropped from 58% to 40%. Mixed forest is considered the most attractive, a finding that tallies with WaMos2. The presence of a shrub layer proved more popular in WaMos3 than in WaMos2. The popularity of deadwood has also increased, but remains at a low level. Forest edges with large trees and those with shrubs have roughly equal appeal. However, the popularity of forest edges with large trees decreased slightly in WaMos3 compared with WaMos2. In the 2020 survey, recreational infrastructure in forests was also rated less highly than in 2010, apart from paths, benches and mulch or other running/jogging tracks: 83% of respondents are satisfied with the amount of infrastructure, and want neither more nor fewer facilities in the forest.

People mainly go to forests to enjoy the fresh air, experience nature, benefit their health or get away from the day-to-day routine. Interestingly, 'being alone' is the only reason to increase in popularity since WaMos2. In line with the reasons cited, 'walking/hiking' is the most common activity, followed by 'observing nature' and 'just being/enjoying peace and quiet/unwinding/spiritual sustenance', the last two activities presumably combined with 'walking/hiking'.

Overall, 88% of people are 'rather satisfied' or 'completely satisfied' with their forest visits. The majority of people find visiting the forest relaxing. Trees, green spaces and nearby forests make a vital contribution to quality of life in towns and cities. However, disturbances during recreational activity have increased. Whereas 74% of people in WaMos2 said they never felt disturbed in the forest, this fell to 54% in WaMos3. As the population grows, there is also a growing trend towards perceived disturbances in forests.

Forest therapies, adventure trails and forest schools

The growing number of people seeking recreation, the diversification of leisure activities, the increase in perceived disturbances and the changes in preferences show that monitoring the recreational use of forests can continue to provide valuable insights in the future. New trends can sometimes take off quickly and draw in large numbers of people. Systematic monitoring can identify new trends early on and provide input for the management of recreational forests. Forest therapies, adventure trails and electric vehicles in forests are currently booming, and forest schools and forest days for school groups are also very much on the up (section 6.11). Guiding visitors, providing infrastructure and ensuring safety and accessibility are among the major resulting challenges facing forest management. At the same time, there is a growing need for recreational users to be informed about forest management. Enhancing communication and involving the public in participatory processes offers opportunities for awareness raising, but also places high demands on staff (Wilkes-Allemann et al. 2022). In any case, forests will continue to play a major role as a recreational space for the public going forward.

6.10 Forests and cultural heritage

Jean-Laurent Pfund

- Forests are an inextricable part of Switzerland's cultural heritage.
- Forests are present in both intangible cultural heritage (through traditions and folklore) and tangible cultural heritage (in the form of special forests and the forest setting of some cultural landmarks). Swiss beech forests were added to the UNESCO World Heritage List in 2021.
- We are currently witnessing a renewed public awareness of nature, as a result of which forests and trees are becoming more deeply embedded in Swiss culture once again. The general public could be involved in an exploration of the cultural value of forests, leading to the inclusion of these values in forest development planning.

Culture is regarded as the set of distinctive spiritual, material, intellectual and emotional features of a society or a social group. Intangible cultural heritage encompasses traditions and practices associated with cultural identity. The Federal Office of Culture updated the Inventory of Living Traditions in Switzerland in 2017 (FOC 2017). This also includes cultural forms with a traditional link to the forest and wood sector, such as wrestling on a sawdust-covered ring ('Schwingen') and shingle-making in the cantons of Fribourg and Vaud. Traditions in urban areas include the Geneva official chestnut tree ('marronnier de la Treille') heralding the arrival of spring, and the May tree in the cantons of Aargau and Basel-Landschaft.

Tangible heritage includes cultural assets created by humans and exceptional natural landscapes. Switzerland has 13 properties listed under the UNESCO World Heritage Convention, including the beech forests in the Valle di Lodano in Ticino and on the Bettlachstock in the canton of Solothurn, which were added to the list in 2021 (UNESCO 2021). Forest also provides a protective setting for around 100 other sites, among them prehistoric burial mounds and forest cemeteries.

Our culture is underpinned by the past, but it remains alive in the form of present-day lifestyles and beliefs. The spiritual values associated with forest in 13 countries, including Switzerland, were analysed by an international research team according to factors such as forest cover (Roux et al. 2022). Indicators were applied to the four stages of forest condition and the respective transitions. According to the team's transition hypothesis, a return to the immaterial values of nature is on the horizon after a period of rational management of nature characterised by economic considerations. Indeed, forest-spirituality and forest-therapy activities are currently on the rise in Switzerland (section 6.9). This transition stage could be beneficial for forest conservation. The general public could be involved in an exploration of the cultural and spiritual value of forests, leading to the inclusion of these values in forest development planning.

Figure 6.10.1

Nature inspires us: Simply rearranging existing natural materials can create places of wonderment (Elfenau, Bern).

Photo: Andreas Bernasconi

6.11 Forest-related education

Gerda Jimmy

- Forests are increasingly being used as a learning space at kindergarten and primary school level.
- As an educational resource, forests offer added value for teaching a range of subjects.
- Secondary school teachers are also keen to integrate forests more widely into their lessons and make more use of them as places of learning.

Forests are increasingly being used as a setting for educational activities. Kindergartens regularly organise forest days, while primary school classes are increasingly spending lessons in the forest, often in collaboration with the forest sector. There also continues to be a demand for projects in which school groups help tend a patch of forest under the supervision of a forestry expert. Guided tours by forest enterprises have proved very popular, and cantonal forest offices have created new jobs in forest-related education.

At primary school level, recent years have seen a growing interest in forests as a place of learning, beyond traditional forest-related education (C. Stocker, Silviva Foundation, personal communication, 27.2.2023). This is because forests offer scope for teaching other subjects, such as maths, in a way that really brings them to life, as well as for learning about forests themselves. The outdoor teaching programme run by the Silviva Foundation and WWF provides teachers with a raft of practical ideas as well as a platform for discussion and training opportunities. A similar trend is in evidence in other European countries, as experience in the European Forest Pedagogics network shows (C. Stocker, Silviva Foundation, personal communication, 27.2.2023).

A study commissioned by the Federal Office for the Environment (FOEN) found that forests were still rarely covered as a subject in secondary schools (Probst et al. 2021). In particular, teaching materials lack content about Swiss forests and little is taught on this topic. However, the study showed that teachers are very interested in activities and guided tours in forests and also in incorporating the subject more into their lessons.

More generally, the interest in forest-related education provides an opportunity to familiarise future generations with forests as an ecosystem worth protecting.

Figure 6.11.1

Forests offer a wide range of opportunities as a learning space, for example through sensory engagement. Photo: FOEN

Glossary

A

Abiotic
Processes and factors that do not involve living organisms. Abiotic → site factors are environmental factors that are not influenced by living organisms, e.g. precipitation or bedrock. → Biotic

Acid
Chemical compound that releases → protons in aqueous solution. → Base

Aerosol
A suspension of solid particles or liquid droplets in air. → Particulate matter

Air pollutants
Pollutants transported by the air. They include → ozone, → ammonia, nitrogen oxides and sulphur dioxide, as well as particulate matter. → Aerosol

Altitudinal vegetation belt
All sites with similar vegetation conditions, taking into account decisive site factors, particularly altitude. In Switzerland there are five main vegetation belts: colline, montane, subalpine, alpine and nival. The boundaries between them are not clearly defined and can change over time.

Ammonia (NH_3)
Pungent, poisonous, gaseous nitrogen compound. Ammonia is mainly released into the environment through agriculture (liquid manure, livestock).

Autochthonous plants
Native plants that have developed naturally in their distribution area or have colonised it without direct or indirect introduction or human intervention.

B

Base
Chemical compound that can absorb → protons. A base can neutralise an → acid.

Base saturation
Percentage of → base cations in the soil's → cation exchange capacity. A high base saturation usually means good nutrient availability for plants, while a low one is characteristic of acidic soils.

BC/Al ratio
Ratio of the → base cations (BC) Ca, Mg and K to inorganic aluminium (Al) in the → soil solution. Measure of → soil acidification.

Biodiversity
Generic term for the diversity of → ecosystems (habitats, biotic communities) and their processes, for species diversity and for genetic diversity within species.

Biodiversity Monitoring (BDM)
A Federal Office for the Environment (FOEN) project to monitor → biodiversity in Switzerland by regularly recording the number of animal and plant species on sample plots. This reveals how biodiversity in Switzerland is developing.

Biomass
The totality of all organic substances of plant or animal origin, including dead material, in an → ecosystem.

Biotic
Processes and factors involving living organisms. Biotic → site factors are environmental factors influenced by living organisms, e.g. competition, harmful organisms or browsing. → Abiotic

Brash mat
Branches and twigs from felled trees that form a lining on a forest aisle. The brash mat protects the forest soil during timber harvesting with forestry machinery and when removing the trees. → Skid trail

C

Carbon (C)
Basic building block of all organic compounds. Burning carbon or carbonaceous compounds leads to the formation of → carbon dioxide (CO_2).

Carbon dioxide (CO_2)
Forms on combustion or decomposition of carbonaceous resources like wood or oil. As a greenhouse gas, CO_2 is responsible for much of today's global warming. Plants absorb CO_2 from the air and incorporate the → carbon (C) into their → biomass. → Photosynthesis

Carbon sink
Reservoir that absorbs and stores → carbon (C). Forests take up carbon during their growth and through the increase in carbon stored in the organic layer, in the soil and in deadwood. They release carbon into the atmosphere when wood is harvested and through decay. If the uptake of carbon is greater than the release, the forest becomes a carbon sink. This definition does not include the storage capacity of wood used for construction.

Carbon source
Opposite of → carbon sink.

Cascade use; cascade principle
Strategy for wood use where the resource is first used as a material, e.g. in furniture or as construction timber, before being burnt at the end of its life cycle to generate energy and heat.

Cations
Positively charged chemical compound. → Cation, base, → Cation exchange capacity

Cation, base
Cation whose hydroxide (OH^-) is a weak → base. Includes the nutrient cations Ca^{2+}, Mg^{2+} and K^+. Also abbreviated to BC. → BC/Al ratio

Cation exchange capacity
Measure of the cation storage potential of soil, calculated as the quantity of exchangeable cations (base cations: Ca^{2+}, Mg^{2+}, K^+, Na^+; acid cations: H^+, Al^{3+}, Fe^{2+}).

Close-to-nature forest management
Management of the forest oriented towards its natural development. 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. Unlike → natural forest, close-to-nature forests are harvested.

Colline belt
see → Altitudinal vegetation belt

Combined heat and power plant (CHP plant)
CHP plants produce electricity from a fuel (e.g. → energy wood) and, at the same time, generate waste heat that can be used for other purposes (e.g. industrial processes or heating). → Special furnaces

Coppice
Basic form of → stand where the trees have grown from coppice (vegetative reproduction through sprouting on rootstocks) or root suckers. Oldest form of regulated forest use, mostly to obtain firewood. Favours tree species that can develop coppice sprouts, like hornbeam and oak. Coppices are managed with short → rotation periods of 10 to 30 years. → High forest

Criterion
In the Forest Report 2025, 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
Level of pollution from the atmosphere (sulphur and nitrogen compounds, heavy metals) that an → ecosystem can tolerate without suffering long-term damage, according to current knowledge.

Crown closure
Horizontal structure of a → stand and measure of the density of the tree crowns. Crown closure refers to the upper layer of the stand, provided this has a → crown coverage of at least 20%. The → NFI distinguishes different degrees of closure: crowded, normal, loose, open, scattered, grouped crowded, grouped normal and heterogeneous.

Crown coverage
Fraction of the total stand area or of an assessed area covered by the vertical projection of the crowns. Areas covered more than once are counted only once. The crown coverage cannot exceed 100%. → Crown closure, → Forest definition

Cryptogam
Flowerless plant that reproduces by spores (mosses, ferns, horsetails), and fungi.

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

D

Deadwood
Lying and standing dead trees and shrubs. → Snag

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. → Natural hazards, gravitational

Defoliation
Loss of foliage of a tree compared with a reference value, where the observer assumes the cause of the deviation to be unknown. The reference value corresponds to the maximum species- and site-specific foliage. Defoliation and tree growth are the → indicators for the development of forest health over an extended period.

Diameter at breast height (dbh)
Stem diameter at 1.3m above ground. → Mid-diameter

Disturbances
Temporally and spatially limited events that lead to the loss of living biomass, e.g. windthrow, bark beetle infestation, forest fire or drought. → Salvage logging

E

Ecological infrastructure
Network of areas that are important for biodiversity. They help to preserve, enhance, re-establish and connect valuable natural and close-to-nature habitats in Switzerland.

Ecosystem
Dynamic, functional unit consisting of all living organisms in a habitat (community). The organisms in an ecosystem interact with their → abiotic and → biotic surroundings and exchange energy, material and information.

Ecosystem service
Benefit that an → ecosystem provides for society, e.g. biomass production or carbon storage. → Forest functions, → Forest ecosystem services

Eleanor (Burglind)
Winter storm that hit Switzerland on 3 January 2018. Burglind was the most powerful winter storm since → Lothar in 1999 and felled around 1.3 million cubic metres of wood, particularly in the Jura and in the lowlands north of the Alps.

Energy wood
Wood that is to be used thermally for energy generation, i.e. by combustion. Energy wood is used as traditional firewood (→ logs), chips, briquettes or pellets. It is classified according to its origin: forest wood, → woodland fragments, → residuals, plantation wood and → waste wood.

Energy wood potential
Amount of wood that can potentially be used for energy. A distinction is made between the theoretical potential and the sustainable potential. While the former reflects an upper limit that is only theoretically obtainable (e.g. the → increment), the latter shows the available potential, taking into account the legal, political, ecological, technical and economic framework conditions.

Ex-situ conservation
Conservation of a species outside its natural habitat, e.g. in specially established collections of living specimens or as seeds in a gene bank. → In-situ conservation

F

Forest Act (ForA)
Federal Act on Forest of 4 October 1991, which came into force on 1 January 1993. There is also an associated Forest Ordinance (ForO) of 30 November 1992. The first Swiss Forest Act came into force in 1876 as the 'Federal Act on the Confederation's Supervision of the Forest Police in the High Mountains' and already contained the principle of sustainable forest management, including in particular the forest conservation requirement. It states that deforestation in non-protective forests is only permitted if the equivalent area is reforested elsewhere.

Forest area
All areas defined as forest according to the → NFI → forest definition. 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 conservation requirement
see → Forest Act (ForA)

Forest definition
A forest is an ecosystem permanently covered with trees. According to the → NFI forest definition, forest is distinguished from non-forest by a → crown coverage ≥ 20%, a dominant height ≥ 3m and a width ≥ 25 to 50m, with the forest width dependent on the → crown coverage.

Forest development plan (FDP)
Management and coordination instrument for the cantonal → forestry agency (also known as the regional forest plan [RFP] in some cantons). FDPs, which are binding on the public authorities, specify which forest ecosystem services are in the public interest based on the → forest functions, and provide guidelines on sustainable forest management. They cover a region or canton and must be coordinated with the cantonal structure plan in accordance with the Spatial Planning Act.

Forest ecosystem services
Economic, health or social benefits that forests provide for individuals or society as a whole. Often used as a synonym for forest → ecosystem services. → Forest functions

Forest edge
Border or transitional area between the vegetation form forest and other elements of the landscape. The forest edge includes the forest mantle (or shelter belt) featuring typical forest-edge trees with → diameter at breast height (dbh) ≥ 12cm, the shrub belt with woody species < 12cm dbh and the herbaceous fringe as an unmanaged or extensively managed buffer zone to intensively cultivated farmland.

Forest enterprise
Organisational unit in the forestry industry which, as a public or private legal entity or natural person, manages forests strategically and operationally. It can consist of one or more forest owners. In Switzerland, it is usually supported by a public authority such as a political commune. To be classed as a forest enterprise in the Federal Statistical Office's → Swiss Forestry Statistics, it must have consolidated accounts for the forest it manages and must manage a minimum forest area (Plateau: 150ha, Jura: 200ha, Pre-Alps: 250ha, Alps and southern side of the Alps: 500ha).

Forest Enterprise Network (FEN)
Network of 160 public forest enterprises whose economic situation is systematically surveyed. The data collected by forest zone and for Switzerland as a whole allow conclusions to be drawn about the entire sector.

Forest Europe
Ministerial conference of 45 European countries and the European Commission aimed at protecting and sustainably managing forests in Europe.

Forest functions
Tasks performed by a forest (forest impacts and potential) or expected of it (human needs). Divided into economic, protective and welfare functions in the Federal Constitution. → Forest ecosystem services

Forest inventory
Periodic assessment of tree and stand attributes as a basis for forest monitoring and planning at enterprise, cantonal or national level. → NFI, → Sanasilva Inventory

Forest zone
Region defined by distinct growing and wood production conditions. Switzerland is divided into the following forest zones: Jura, (Swiss) Plateau, Pre-Alps, Alps and the southern side of the Alps (i.e. areas south of the main Alpine ridge). Also known as production regions in the → NFI.

Forestry agency
Federal or cantonal administrative agency that ensures forest legislation is implemented. In the cantons, forest areas are divided up into forestry districts and forestry sections.

Forestry Statistics, Swiss
Annual surveys by the Federal Statistical Office on the quantity of timber prepared in forests by assortment and type of wood, on planting and on operational financial data (excluding small forest owners). They involve a complete survey of all forest enterprises and partial surveys of the → Forest Enterprise Network (FEN).

FSC
Abbreviation for 'Forest Stewardship Council'. International organisation of environmental groups, indigenous peoples and forestry and timber industry businesses, founded in 1993. Promotes the ecologically and socially sustainable use of forests and certifies appropriately produced wood with the FSC label. → PEFC

G

Gene conservation units
Spatially defined forest areas that are designated and protected for the long-term conservation of the genetic diversity of important main tree species.

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

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

Giants
Trees with a → diameter at breast height (dbh) > 80cm. They are ecologically particularly valuable because they provide → habitats for many animal and insect species due to their large wood volume, thick bark and usually very thick and highly structured crowns.

Gross increment
see → Increment

Gross value added
Value of all products and services produced by a country in a year after deducting the input costs, i.e. the cost of products or services used, processed or transformed during the production process.

Group selection system (or femel system)
Form of → stand management in which patches of forest (usually small patches in Switzerland) are regenerated through a combination of different types of harvesting (shelterwood, group selection or strip felling). This results in stands with → stages of development that can be clearly distinguished from one another based on their tree dimensions. → Permanent forest, → Plenter forest

Groundwater protection zone
Most important planning instrument for the protection of drinking water. The cantons are required to designate protection zones with graduated degrees of protection around all groundwater wells of public interest. Zone S1 serves to directly protect the drinking-water intake facility. Zone S2 protects the drinking-water intake facility from harmful influences and structural interventions. Zone S3 is a buffer zone in the transition to the adjoining water protection area and contains restrictions on use and measures for general hazard prevention. Since 2017, highly heterogeneous karst or fractured aquifers have also been protected with the zones Sh (h = highly vulnerable) and Sm (m = medium vulnerable).

Growing stock
→ Stemwood (usually in cubic metres per hectare) of all living trees and shrubs (standing and lying) ≥ 12cm in → diameter at breast height (dbh) with bark in a → stand or area.

H

Habitat
Habitat of a plant or animal species, comprising all the ecological and environmental factors of a community.

Habitat tree
Also known as a biotope tree. Living tree with habitat structures such as woodpecker cavities, → rot-holes, nests of large birds (birds of prey and owls), bracket fungi, lightning scars, large dead branches in the crown, wood mould and bark pockets or surface sap flow.

Heterozygosity
Individuals with different maternal and paternal genes (alleles) at a gene locus are heterozygous with regard to that locus. The degree of heterozygosity (in %) indicates how many gene loci are heterozygous in an individual tree or how high this value is on average for all trees in a population. It is used as a measure of genetic diversity within populations.

High forest
Basic form of → stand where the trees are mainly standards (trees grown from seeds or cuttings). A distinction is made between uniform high forest and → plenter forest. The former consists of homogeneous, spatially and temporally clearly definable stands with a layered structure, in which the trees forming the main stand have similar → diameters at breast height (dbh) and can thus be assigned to the same → stage of development. In the group selection management system, → regeneration of high forest involves harvesting all trees in certain areas at the end of the → rotation period. → Coppice

Humus
All the dead carbonaceous (organic) matter in the organic layer and in the soil (depth of 0–100cm). → Topsoil

I

Increment
In the → NFI, gross increment in wood volume. Includes the increase in → stemwood volume with bark of the trees and shrubs surviving between two inventories with a diameter at breast height (dbh) ≥ 12cm, the stemwood volume with bark of all ingrowth, and the modelled increase in stemwood volume with bark of losses during half the inventory period. → Net increment

Indicator
A simple, measurable parameter for complex matters, systems or processes. Used in the → NFI for attributes with special information content related to the → criteria for monitoring sustainability.

Industrial wood
Raw wood that is mechanically shredded or chemically pulped. Used to produce mechanical and chemical pulp for papermaking, wood shavings, particle- and fibreboard and other industrial products.

In-situ conservation
Targeted conservation of a species within its natural habitat. → Ex-situ conservation

Integral forest and wood strategy 2050
National strategy to replace and merge forest policy and wood resource policy from 2025 onwards. Includes a holistic approach (balance of protection and use) taking into account all sectoral objectives (climate, energy, biodiversity, spatial planning, regional economy, agriculture, circular economy, security, bioeconomy, etc.).

Intercantonal Forest Observation Programme (WDB)
Research programme for long-term forest monitoring, run since 1984 by the Institute for Applied Plant Biology (IAP) on behalf of (currently) 13 cantons and the FOEN. The health and vitality of forests on 190 observation plots is regularly recorded, in particular forest growth and the nutrient balance of the soil.

Invasive species, non-native
Introduced species that is known or assumed to be spreading in Switzerland and may reach a population density that impairs biodiversity and its sustainable use or endangers humans, animals or the environment.

L

Logs
Dried, sawn and split forest wood used as → energy wood.

Long-Term Forest Ecosystem Research (LWF)
Research programme examining the long-term effects of natural and human-induced pressures on forests. The LWF is based on a network of plots and measurement series forming part of the → UNECE network (49 → Sanasilva Inventory plots on a systematic 16×16km grid and 19 long-term research plots, supplemented with other experimental sites).

Lothar
Intense low-pressure system that passed over Western and Central Europe on 26 December 1999. The storm caused damage totalling almost CHF 1.8 billion in Switzerland.

M

Mid-diameter
Diameter of round stack wood, measured in the centre of the trunk, usually under the bark. → Diameter at breast height (dbh)

Mycorrhiza
Symbiosis between a fungus and a plant in which the fungus is in contact with the plant's fine root system. The mycorrhizal fungi supply the plant with nutrients and water from the soil and in return receive the glucose produced by photosynthesis from the green plant.

N

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

National Forest Inventory (NFI)
Sampling inventory of roughly 6,500 sample plots throughout Switzerland. It periodically records the condition of 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 fifth inventory is ongoing (NFI5 2018–26). The results of the NFI5 interim evaluation (2018–22) have been incorporated into the Forest Report 2025. Previous inventories took place in 1983–85 (NFI1), 1993–95 (NFI2), 2004–06 (NFI3) and 2009–17 (NFI4). Since 2009, the data have been continuously collected, with one ninth of the sample plots surveyed each year. The primary data sources are aerial images, data collected in forests and surveys of → forestry agencies.

National Priority Species, National Priority Habitats
Lists of animal and plant species and habitats that the Confederation has defined as priorities for species promotion in Switzerland. Prioritisation is based on how endangered a species or habitat is and how responsible Switzerland is for its survival.

Natural forest
Forest that has resulted from → natural regeneration and that has developed freely for a long time without human intervention. In the → NFI, all forests that have not been managed or grazed by livestock for more than 100 years, have developed purely from natural regeneration and have a close-to-nature proportion of conifers are considered natural forests.

Natural hazards, gravitational
Downslope movements such as fall processes, avalanches, landslides, debris flow and flooding.

Natural regeneration
→ Regeneration resulting naturally from seeding or vegetative reproduction.

Neophyte
Plant species intentionally or unintentionally introduced by humans into a habitat outside its natural range after 1492 (Columbus's voyage to America).

Net increment
→ Increment of wood volume minus the volume of mortality.

Nitrate (NO_3^-)
Nitrogen-oxygen compound easily soluble in water. Plants meet their nitrogen requirements by, among other things, absorbing nitrates from groundwater.

Nitrate leaching
Annual quantity of → nitrate (NO_3^-) leached from the root zone into watercourses or into the groundwater.

Nitrogen (N)
Important plant nutrient. Nitrogen (N_2) is a colourless and odourless gas and the main component of air. To be taken up by plants, atmospheric nitrogen must be converted into → nitrate (NO_3^-) or ammonium (NH_4^+).

Nut orchard
Park-like meadow planted with sweet chestnut or walnut trees, which is used for wood and fruit as well as for hay production or as pasture. Mainly found on the southern side of the Alps. An increasingly important agroforestry practice for sustainable agricultural production. → Wooded pasture

O

Old-growth patch
Generally 1 to 5ha stand of mainly older trees that are left to decay naturally. Old-growth patches serve to enrich old timber stands and → deadwood in managed forests.

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

Organic layer
Top layer of forest soil consisting of organic vegetation residues in various stages of decomposition. → Topsoil

Overbank sedimentation
Deposition of mostly coarse solid material that spills out of a watercourse bed during flooding. → Natural hazards, gravitational

Ozone (O_3)
Highly reactive oxygen compound. Trace gas in the atmosphere. High in the stratosphere, the ozone layer shields the Earth against harmful ultraviolet rays. Close to the ground, even low ozone concentrations may be harmful, irritating human respiratory systems and damaging the photosynthetically active cells in the leaves of plants.

Ozone flux
Amount of → ozone taken up through the stomata of leaves and needles. The extent of the ozone flux depends on both the tree species and the environmental conditions. → POD

P

Parasite
A parasitic organism lives on or inside other living organisms and derives nutrients from them.

Paris Agreement
Agreement negotiated at the 2015 Paris Climate Change Conference which requires all countries to reduce greenhouse gas emissions. It replaced the 1997 Kyoto Protocol and extended the emissions targets to all the world's nations. Switzerland ratified the agreement on 6 October 2017.

Particulate matter
The finest particles in air produced through different processes (combustion, mechanical abrasion, secondary formation from gaseous precursor pollutants). → Aerosol

PEFC
Abbreviation for 'Programme for the Endorsement of Forest Certification'. Independent certification system to promote and continually improve sustainable forest management. → FSC

Permanent forest
Form of → stand management in which the forest is not rejuvenated by harvesting large areas but by removing individual mature trees (→ plenter forest) or small groups of trees (group and mountain plenter forest). This results in a non-uniform forest in which all generations of trees occur side by side in small or even very small areas. → Group selection system

Photosynthesis
Biochemical process in which plants use the energy from sunlight to produce glucose and oxygen from → carbon dioxide (CO_2) and water and so build → biomass.

pH value
Unit of measurement for the concentration of → protons in an aqueous environment such as a → soil solution or rain. The lower the pH value, the higher the concentration of protons. Liquids with a pH value of 7 are neutral, those over 7 are alkaline (basic) and those under 7 are acidic.

Pioneer species
Plant species that appears early in the → succession. Pioneer species typically produce large quantities of easily dispersible seeds, fructificate annually, grow rapidly when young, have a low tolerance for shade and a high tolerance for extreme climatic conditions, and often have a short lifespan.

Planting
Activity in which trees or shrubs grown from seed (seedlings) or vegetatively are placed in their final location in the forest. Often used to aid forest → regeneration, e.g. after storm damage. → Natural regeneration

Plasticity
Change in the external characteristics of an individual in response to changing environmental factors. Also external differences between individuals with identical genotypes (clones) or at least very similar genotypes. Often a consequence of altered gene expression.

Plenter forest
Also known as 'single-tree selection forest'. → High forest with a vertically stratified structure. In this type of → stand, trees of all sizes grow side by side. A plenter forest is always managed by harvesting single stems (single-tree selection or plenter selection). The aim of this is to use mature stems, select valuable trees, preserve the vertically stratified → stand structure on a small scale and promote continuous → regeneration.

POD
Phytotoxic ozone dose. Index for the ozone dose taken up by a plant via the stomata. → Ozone flux

Primary function
If a forest or woodland performs several → forest functions simultaneously, the most important of these is called the primary function. In the → NFI, this is the forest function that has priority should the district foresters find conflicts over use, with the other forest functions also being considered where possible.

Pristine forest
Forest where earlier human use is not known or detectable or where it is so insignificant and so long ago that it has no influence on the tree species composition, forest structure, deadwood quantity and forest dynamics. A pristine forest typically contains large quantities of → deadwood because the wood from dead trees is left lying.

Proton
Positively charged hydrogen atom (H^+). In aqueous solutions, protons are released by → acids and absorbed by → bases. Acid soils contain high concentrations of protons. → pH value

Provenance
Place of origin of → seed or of young trees for → planting. For example, beech trees from the Sihlwald are considered a valuable provenance because of their growth characteristics. Due to climate change, native species originating in drier and warmer regions are gaining in importance.

R

Regeneration
Establishment and growth of young trees. Regeneration can be promoted via silvicultural measures (e.g. secondary felling for → natural regeneration) or occur as the result of → planting. Also used as a term for a collective of young trees.

Residuals (forest residues)
Part of timber harvest that cannot be used as → round stack wood. Brushwood as well as stems and branches that do not have the lengths and diameters required for the round stack wood assortments. Used to produce energy and occasionally as a material.

Residuals (industrial)
Residues such as wood shavings and sawdust from wood processing, e.g. in sawmills, planing mills and carpenters' workshops. Used as a material and for energy production.

Resilience
Ability of an → ecosystem to maintain a state of equilibrium despite diverse ecological disturbances.

Risk management, integrated
Management taking into account all natural hazards and measures and involving all those responsible for planning and implementing these measures. Aimed at achieving ecological, economic and social sustainability.

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. → Coppice forest, → High forest

Rot-hole
Tree cavity in which wood mould (a mixture of heavily decomposed, soft wood, plant remains and remains of animal faeces) has been deposited. Rot-holes provide a valuable → habitat for rare and highly specialised species.

Round stack wood
Cover term for the raw and unworked wood produced in the forest during → wood harvesting in the form of → stemwood, → industrial wood and → energy wood. A distinction is made between broadleaved and conifer round stack wood according to the tree species.

S

Salvage logging
Unplanned logging of forest stands due to → disturbances.

Sanasilva Inventory
Annual inventory of the → defoliation and mortality rate on around 50 plots, on a systematic subset of the → NFI network. It is part of the 16×16km representative network of → UNECE for the whole of Europe. → Forest inventory

Saprophytes
Organisms, especially fungi and bacteria, that feed on dead organic matter (wood, plant parts, leaves, needles, cones, horn, dead animals, etc.) because they cannot photosynthesise.

Saproxylic species
Fungi or animals that wholly or partly feed on, live in or use wood in at least one of their life stages. The term is mostly used for insects.

Sawn timber
Products produced in sawmills by cutting → stemwood to produce, for example, boards and battens for the construction, packaging and furniture industries.

Seed
Seed used to grow young tree seedlings, collected directly from parent 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.

Shrub forest
→ Stand where more than two thirds of the area is covered with shrubs, according to the → NFI definition. Typical examples include forests of green alder and dwarf mountain-pine, as well as hazel (coppice) forests and similar stockings.

Shrub layer
Layer in the vertical → stand structure formed primarily by shrubs with a maximum height of 5m. → Tree layer

Site factors
Totality of all environmental influences that affect living organisms at a particular location. Site factors include → biotic and → abiotic environmental influences. Primary site factors, e.g. water, temperature, light, chemical and mechanical factors, have a direct effect. Secondary site factors, e.g. climatic factors, altitude or biotic factors in the soil, have an indirect effect.

Skid trail
A forest aisle that is free of stocking, created in terrain accessible to tractors without constructing a track. It is used to transport timber from the forest to the nearest truck road. → Brash mat

Slippage
Tearing up of the forest soil when heavy forestry machinery is driven over it during timber harvesting due to the frictional forces of the wheels or tracks. Slippage can be reduced with technical measures.

Snag
Standing dead tree. In the → NFI, dead tree or shrub ≥ 12cm in diameter at breast height (dbh).

Socio-Cultural Forest Monitoring (WaMos)
Periodic survey of the public's relationship to Swiss forests, conducted in 1997 (WaMos 1) and 2010 (WaMos 2) as representative telephone surveys and in 2020 (WaMos 3) as a representative online survey.

Soil 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 soil's → pH value falls, the → base saturation decreases and 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. → Cation exchange capacity

Soil solution
Water content of the soil including the substances dissolved in it. Performs the important function of transport and reaction medium in the soil.

Solid cubic metre (scm)
Unit of measurement for → round stack wood. A solid cubic metre corresponds to one cubic metre of solid wood mass, usually without bark. The unit of measurement is used in harvesting and selling round stack wood.

Special furnaces
Furnaces 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. → Combined heat and power plant

Stage of development
Stage of stand development defined based on the mean or dominant tree size measure (diameter or height). In the → NFI, the stages of development distinguished on the basis of the dominant → diameter at breast height (dbhdom) are: → young growth/thicket (< 12cm), pole timber (12–30cm), young timber (31–40cm), medium timber (41–50cm) and old timber (> 50cm).

Stand
Tree collective that differs significantly from the surrounding trees in terms of species composition, stand age or structure. It represents the smallest spatial unit for silvicultural activities and the → forest inventory.

Stand, crowded or dense
→ Stand in which the tree crowns are in close contact and influence each other, often resulting in deformed crowns. → Crown closure

Stand structure
Vertical formation of a stand, defined by the proportions of the stand layers (upper, middle and lower layers) as single-layered, multi-layered, stratified or clustered.

Stemwood
→ round stack wood used as more valuable → sawn timber or veneers.

Structural diversity
In the → NFI, indicator for characterising the → stand as a habitat. It is derived from the following attributes: → stage of development, → crown closure, → stand structure, proportion of old timber, degree of damage to the stand, presence of forest or stand edge, occurrence and type of gaps, → crown coverage of the → shrub layer, crown coverage of berry bushes, as well as the occurrence of stumps, lying → deadwood, → snags and heaps of branches.

Succession
The chronological sequence, uninfluenced by humans, of the growth of different plant and animal communities on the same site. The forest succession is a sequence from pioneer communities with light-demanding tree species to climax forest communities with shade-tolerant tree species. → Pioneer species

Sustainability
Principle of forest management aimed at preserving forests and their diverse functions and services in the long term. → Forest functions, → Forest ecosystem services

Swiss Bird Index (SBI®)
Indicator of the Swiss Ornithological Institute in Sempach, recording the development of breeding birds in Switzerland since 1990. The SBI® Woodland sub-index analyses 56 bird species for which sufficient population development data are available.

T

Target species
Animal or plant species whose conservation and promotion is the direct, specific objective of protection and management measures. At least a → National Priority Species. The success of the measures is measured by the actual occurrence of the target species. → Umbrella species

Topsoil
Second layer of forest soil, also known as the A horizon, consisting of mineral soil and humus. → Organic layer

Total wood volume
→ Stemwood volume of all living and dead trees and shrubs (standing and lying) with a → diameter at breast height (dbh) ≥ 12cm. The total wood volume is the sum of the → growing stock and → deadwood volumes.

Tree layer
Vegetation layer consisting primarily of trees. The tree layer determines the forest's composition and structure, contains the largest proportion of its biomass and controls many important → ecosystem services and functions. → Shrub layer

U

Umbrella species
Target species in conservation. Protecting an umbrella species simultaneously benefits many other species in the same habitat.

UNECE
Abbreviation for 'United Nations Economic Commission for Europe'. Based in Geneva. Founded in 1947 as one of five regional organisations. UNECE's primary goal is to promote economic cooperation among its 56 member states.

V

Vascular plants
Plants that have a stable tube system (trachea) for transporting water. Vascular plants are tripartite, consisting of roots, a stem and leaves. Subdivided into pteridophytes (ferns, horsetails) and spermatophytes or seed plants (trees, shrubs, grasses, flowers).

Vitality
Quality of a tree determined by its genetic make-up and environmental conditions. Vitality is manifested in particular in a tree's ability to adapt and compete.

Vivian
Intense low-pressure system that caused great damage in Europe, including 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 (VOCs)
Group of carbonaceous compounds that evaporate easily. They may contain toxic components.

W

Waste wood
Wood that is no longer part of the use processes. It stems, for example, from demolished buildings and the disposal of furniture and packaging. Treated or natural, i.e. untreated, depending on its origin.

Weathering
Disintegration/dissolving and transformation of rocks and minerals in forest soil. Chemical weathering is the most important acid-neutralising process in soil and the most important source of nutrients for plants. → Soil acidification

Wild ungulates
Collective term for wild even-toed ungulates. In the → NFI, the term covers red deer, roe deer and chamois.

Wood (or timber) harvesting
Removal of trees from the forest. The process of timber harvesting involves logging (harvesting and processing, removing branches and cross-cutting the wood), extracting and stacking the stems and trees (transporting to forest track) and storing them at suitable sites until they are transported by road to the plant. → Skid trail

Wooded pasture
Pasture stocked with forest trees, subject to forest legislation. Wooded pastures are open forest landscapes with a pattern of small patches of pasture and forest. They developed from extensive grazing and are now very valuable for nature conservation. The most attractive are in the Jura highlands and Central Alps. → Nut orchard

Woodland fragments
Wood that grows outside of forests in open country. Includes wood from residential areas, roadsides or embankments and from the maintenance of hedges or individual trees.

Y

Young forest
→ Stand whose → stage of development is → young growth/thicket and weak pole timber. In the → NFI, all stands with a dominant → diameter at breast height (dbhdom) < 12cm are considered young forest.

Young growth/thicket
→ Stage of development of a → stand in which the 100 tallest trees per hectare are, on average, no higher than 1.3m. The young forest trees do not form a closed stand and belong to the herb or → shrub layer.

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