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Self-Assessment Report

WSL Evaluation 2022, Volume 1



Swiss Federal Institute for Forest, Snow
and Landscape Research WSL

WSL Institute for Snow and Avalanche Research SLF

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Research for People and the Environment: The Swiss Federal Institute for Forest Snow and Landscape Research WSL monitors and studies forest, landscape, biodiversity, natural hazards, and snow and ice. WSL is a research institute of the Swiss Confederation and part of the ETH Domain. The WSL Institute for Snow and Avalanche Research SLF has been part of the WSL since 1989.



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Preface

Periodic evaluations are necessary and important in science, in particular in publicly funded institutions. They provide the framework to critically reflect on what has been achieved during the last period and to look ahead to future opportunities. To ensure good governance and management of the institutions within the ETH Domain, periodic evaluations are conducted in which the quality of research, teaching and services is reviewed.

Such an institutional evaluation is due to take place at WSL in late 2022, nine years after the last evaluation. This self-assessment report (SAR) supports the evaluation process by providing key information about WSL. The three-day site visit by the evaluation committee – the core part of the evaluation – will take place from 29 November to 2 December 2022. The first two days will be held at the main WSL site in Birmensdorf, near Zurich, and the third at the WSL Institute for Snow and Avalanche Research SLF in Davos (Grisons). The final report from the evaluation panel will be sent to WSL by early 2023. Finally, the evaluation report and a written response to it by WSL will be delivered to the ETH Board in early spring 2023.

Since the last evaluation in 2013, WSL has continued to develop thematically, and the scientific output and contributions to science-based decision-making by WSL employees have increased steadily to a high level. At the same time, several key global and societal challenges that are directly related to WSL's core thematic areas have become increasingly pressing, such as the impacts of climate change, biodiversity loss and deterioration of ecosystem services, the increasing frequency and intensity of natural hazards, and the growing pressure on forests due to diverging societal demands and environmental impacts. WSL has its finger on the pulse of all these crucial topics.

The evaluation in 2022 and the accompanying SAR are thus an important opportunity for WSL to present the excellent work conducted at this research institute in its broad thematic areas, in terms of research, knowledge transfer and – of particular importance to WSL – science-based application in practice, and outreach to society and politics. Moreover, the evaluation process will illustrate the high level of engagement and enthusiasm of WSL employees and the institute's sincere commitment to contributing knowledge and expertise, in line with WSL's vision to conduct “research for people and the environment”. Finally, the evaluation and SAR will highlight that, as the only federal institute for terrestrial environmental research in Switzerland, WSL is well positioned to seize future opportunities that arise and to actively address challenges and seek sustainable solutions, together with partners from science, practice and society. The key message is that WSL serves Switzerland through excellent science that is highly relevant at the local, national and global levels, and through leadership in the field of terrestrial environmental research.



Beate Jessel

WSL Director

Figure 1.1: Number of employees (and percentage of the 657 staff total) at the WSL headquarters in Birmensdorf and at the other four WSL sites in Switzerland at the end of 2021.

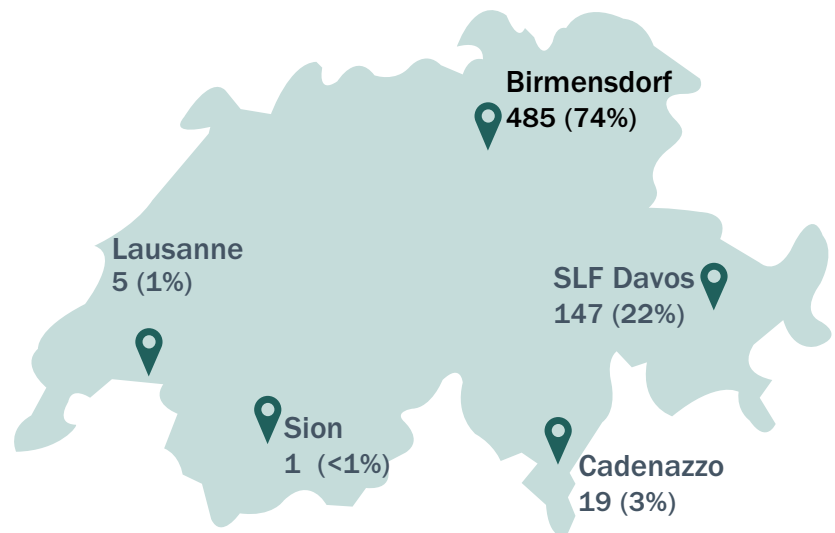


Figure 1.2: Aerial images of the WSL sites in Birmensdorf (above) and Davos (SLF; below). Photos: R. Boesch and Y. Bühler, WSL.

1 Introduction

Reference to ToRs:

Introduction to WSL
and background of
evaluation and all ToRs

The Swiss Federal Institute for Forest, Snow and Landscape Research WSL is the Swiss Confederation's research institute for terrestrial environmental systems. It is part of the ETH Domain, which comprises the ETH Board (the strategic management body), two Federal Institutes of Technology – in Zurich (ETH Zurich) and Lausanne (EPFL), and four research institutes: the Paul Scherrer Institute (PSI), the Swiss Federal Laboratories for Materials Science and Technology (Empa), the Swiss Federal Institute of Aquatic Science and Technology (Eawag), and WSL. Each of the six institutions in the ETH Domain has to be evaluated at least once within an eight-year period.

The self-assessment report (SAR; see Appendix IV for a list of abbreviations used in this document) of WSL for the evaluation in 2022 comprises two volumes that provide the information necessary to support the evaluation process. This Volume 1 briefly lays out the boundary conditions of the evaluation and introduces WSL as a Swiss federal research institute, including its mandate, positioning, organization, core activities and future opportunities. Volume 2 then provides a short overview of the scopes, tasks and selected highlights of all organizational units of WSL. See Box 1 for more details and background on the evaluation process.

1.1 WSL's mission

WSL aims for excellence in research at the international level that results in benefits for Swiss society. Based on its vision of “research for people and the environment” and its research in five core thematic areas (forest, biodiversity, landscape, natural hazards, and snow and ice), WSL develops science-based options for sustainable approaches to the environment, together with partners from science, practice and society. WSL's main fields of activity are thus: excellent research, knowledge transfer and application in practice, and outreach to society and politics.

*Text in italics links
to online resources
in the digital version
of the report.*

1.2 Numbers, sites and regional anchorage in Switzerland

At the end of 2021, WSL had 657 employees, including apprentices, interns and temporary staff. In addition, WSL hosts a large number of scientific guests and bachelor's and master's students who are affiliated with or enrolled at a university (not on WSL's payroll). Two-thirds of WSL staff are from Switzerland, and one-third come from about 40 countries around the globe. The overall proportion of women was 40% at the end of 2021. About 60% of the staff are scientific employees (including PhD students and postdocs), 30% are technical staff, and 10% are administrative staff (including HR, finance and communication specialists). WSL is committed to providing vocational training by offering apprenticeships. At the end of 2021, WSL employed a total of 13 apprentices; they received training in 7 professions, such as IT specialist and laboratory technician.

WSL employees work at five locations in all language regions of Switzerland (Figure 1.1) and conduct research at many thousands of research sites throughout Switzerland. Along with the main WSL office in Birmensdorf, near Zurich, and the WSL Institute for Snow and Avalanche Research SLF in Davos (Figure 1.2), smaller stations are located in Cadenazzo, Lausanne and Sion. The regional anchoring is a central success factor for the co-operation and establishment of synergies with cantonal and local authorities, as it allows WSL to maintain contacts with practitioners in all four national languages and to act as a bridge from science to implementation.

About the WSL evaluation 2022

Good governance and management of the institutions of the ETH Domain require periodic evaluations in order to review the quality of teaching, research and services. The Federal Act on the Federal Institutes of Technology (ETH Act; Appendix II WSL Legal Mandate) explicitly places the responsibility for quality assurance in the hands of the institutions of the ETH Domain, under the supervision of the ETH Board.

Each of the six institutions of the ETH Domain has to be evaluated at least once within an eight-year period. The evaluations are commissioned by the Executive Board of ETH Zurich or EPFL, or by the Directorate of a research institute. Thus, this evaluation was commissioned by the WSL Directorate after the ETH Board approved the terms of reference (ToRs). The evaluation results are brought to the attention of the ETH Board, who then makes further decisions. The last evaluation of WSL took place in 2013. Due to the change in the WSL Director position in 2021, the current evaluation was postponed by one year to 2022.

The evaluation process is guided by a set of terms of reference (ToRs), i.e., the questions to be addressed by the evaluators (see below). It was the responsibility of the WSL Directorate to draft ToRs for the upcoming evaluation, following the guidance provided by the ETH Board. The ETH Board has approved the ToRs and thus mandated WSL to conduct the evaluation in 2022 as suggested (see Box ToRs). While the SAR struc-

ture does not strictly follow the structure of the ToRs, it provides a comprehensive overview of WSL and its activities, aiming to address all the questions and aspects covered in the ToRs. To help the reader link the sections of the SAR to the ToRs, information relevant to a particular ToR in a particular SAR section is indicated in the margins in the SAR.

The ToRs take into account WSL's main fields of activity: excellent research, knowledge transfer and application in practice, and outreach to society and politics. According to the provisions for evaluations within the ETH Domain, the ToRs include a set of five overarching questions on WSL's: (1) relevance, (2) quality, (3) productivity, (4) dynamics, and (5) opportunities. In addition, they comprise a set of nine specific questions in the following five categories: (1) institutional level, (2) strategic focus, (3) long-term research and monitoring, (4) education, and (5) stakeholder involvement and role in society.

The evaluation is conducted by an international panel comprising eight renowned scientists and stakeholders with broad expertise in the core thematic areas of WSL. While the panel has to cover a broad range of institutions, expertise and experience relevant to WSL, its members must not have close ties to WSL or its employees in order to avoid conflicts of interest. The evaluation panel is led by a chairperson who coordinates work within the panel of experts (see Box Panel members).

Panel members

Volker Mosbrugger (Chair)	Germany	Senckenberg Gesellschaft für Naturforschung, Polytechnische Gesellschaft
Wolfgang Cramer	France	Institut Méditerranéen de Biodiversité et d'Ecologie Marine et Continentale, CNRS
Lena Gustafsson	Sweden	Department of Ecology, Swedish University of Agricultural Sciences
Bernd Hansjürgens	Germany	UFZ Helmholtz Center for Environmental Research
Ueli Meier	Switzerland	Amt für Wald beider Basel
Joan Nassauer	USA	School for Environment & Sustainability, University of Michigan
John Pomeroy	Canada	Department of Geography & Planning, University of Saskatchewan
Julienne Stroeve	UK/Canada	University College London & Centre for Earth Observations Sciences, University of Manitoba

Terms of reference (ToRs)

I. Overarching questions

- (1) **Relevance:** Are WSL's research, knowledge transfer/application, and outreach activities relevant to science, practice and society/policy, and are they overall well balanced?
- (2) **Quality:** Are WSL's research, knowledge transfer/application, and outreach activities well recognized internationally and nationally?
- (3) **Productivity:** How substantial are the amount and diversity of WSL's research, knowledge transfer/application, and outreach activities at the national and international levels?
- (4) **Dynamics:** Is WSL flexible enough to respond to emerging issues of scientific and societal relevance and to pursue promising opportunities? Are WSL's collaborative programs an agile tool to achieve the goals stated in its mission statement?
- (5) **Opportunities:** Does the Peer Review Committee see emerging topics of scientific or societal relevance in WSL's core research, knowledge transfer/application, and outreach themes that should be added to WSL's portfolio?

II. Specific questions

Institutional level

- (a) Do WSL's organizational and management structures best serve the topics and crosscutting issues that need to be addressed to fulfill its mandate?
- (b) Does WSL's physical and digital infrastructure provide the necessary support for research, knowledge transfer/application, and outreach?
- (c) How successful/adequate are WSL's efforts to promote diversity, an inclusive environment, and scientific integrity?

Strategic focus

- (d) How relevant are the strategic topics and corresponding activities that WSL would like to address in the future? Does the Peer Review Committee identify further key aspects that should be considered?
- (e) Are WSL's collaborations across its research units, with partners in the ETH Domain, and with partners at the cantonal, national and international levels appropriate and well balanced to address its strategic topics?

Long-term research and monitoring

- (f) Does WSL put its long-term monitoring activities and infrastructure appropriately in value in its research, knowledge transfer/application, and outreach?
- (g) Are the long-term research and monitoring activities well positioned to address current and future challenges?

Education

- (h) Does WSL adequately contribute its specific knowledge and expertise to teaching activities at universities?

Stakeholder involvement and role in society

- (i) How balanced, interconnected and adequately responsive to stakeholder needs are WSL's research, knowledge transfer/application, and outreach activities?

2 Background

WSL's research currently covers a wide range of themes and environments. When its predecessor institutes were founded, the Central Station for Experimental Forestry in Zurich and later the Snow Laboratory in Davos, their foci were largely forest management, hydrology and snow research. The two original institutes merged in 1989 to form the modern environmental research institute, WSL, with landscape as a prominent new focus in its institutional name. Over the years, WSL has grown in thematic breadth and size and has become a federal research institute of the ETH Domain.

2.1 History and development of WSL

WSL's history extends back to the mid 1850s, when the National Council adopted the Federal Polytechnic School Act, which laid the groundwork for the opening in 1855 of what is today ETH Zurich. In 1880, the Polytechnic School established a forestry institute, which developed into the Swiss Central Institute for Forest Research in 1885. In 1933, the Swiss Central Institute for Forest Research became the Federal Institute for Forest Research (EAFV) with, for the first time, a full-time director.

In the early 1950s, the scope of EAFV's research areas expanded greatly with the addition of wood technology, phytopathology, entomology and vegetation science. In 1958, EAFV needed more space and moved to the current WSL site in Birmensdorf, with new buildings and an experimental garden. Landscape research became established at EAFV in the 1970s, especially after 1976, when the first inventory was initiated on nationally important habitats, namely Swiss mires and bogs. With increasing air pollution, better information on its environmental effects was needed and EAFV also began to focus on anthropogenic impacts on the environment in general.

In 1936, snow research started on Weissfluhjoch (2662 m a.s.l.) above Davos in response to the increasing need for avalanche protection by the tourism industry, railway companies and hydropower firms. In 1943, the first building of the Swiss Federal Institute for Snow and Avalanche Research, Davos-Weissfluhjoch (EISLF) was opened. In 1945, EISLF took over responsibility for avalanche warning, which until then had been the responsibility of the Swiss army. The avalanche winter of 1951, with almost one hundred victims, was a turning point for EISLF, with a shift towards more applied research on avalanche protection. EISLF then continuously integrated new research findings to provide up-to-date support for the various tasks performed for the Confederation (see Section 2.4). Since the forest plays an important role in avalanche protection, collaboration with EAFV also began at that time.

EAFV and EISLF developed in parallel over the years as separate federal institutes. Both dealt with queries arising from changing conditions in society and the environment, for which they developed scientifically sound solutions. In 1975 the first joint project of EAFV and EISLF was carried out: the planting of the Stillberg experimental afforestation near Davos. Finally, in 1989 EISLF and EAFV merged and WSL was created, including the Swiss Institute for Avalanche Research SLF in Davos. WSL's tasks today also include the preservation and promotion of biodiversity, the use and protection of natural habitats and cultural landscapes, and protection against natural hazards in general.

In 1991, following a political request to reflect the diversity of Switzerland, WSL established branches in Italian-speaking Ticino (Bellinzona, now Cadenazzo) and in the French-speaking region of Switzerland (Lausanne, at EPFL). In 1995 another site was

Reference to ToRs:

I. Overarching questions

- (1) Relevance
- (3) Productivity

II. Specific questions

Institutional level (a)(b)(c)

Strategic focus (d)(e)

Long-term research and monitoring (f)(g)

Education (h)

Stakeholder involvement and role in society (i)

opened, in Sion, to operate and manage some of the large experimental infrastructures of WSL in the southern Alpine region of Switzerland.

2.2 Position in the ETH Domain

WSL has been part of the ETH Domain since the Domain's creation in 1989. As with the other five institutions of the ETH Domain, it is an autonomous body of the Federal Confederation established under public law and with its own legal persona (see Appendix II WSL Legal Mandate).

Together, ETH Zurich, EPFL and the four research institutes share the responsibility to fulfill the mandate and the strategic goals of the Federal Council to the ETH Domain in education, research, knowledge and technology transfer (KTT), and services. All six institutions develop their own strategies to support the development of the overarching strategy of the ETH Domain (Figure 2.1).

The two federal universities bear the fundamental responsibility for tertiary education in their respective fields. They are oriented towards basic science and grant academic degrees. The research institutes do not grant academic degrees. Instead, their educational mandate is fulfilled in partnership with ETH Zurich and EPFL or other universities in Switzerland or abroad.

The research institutes are legally bound to the thematic scope of their activities (see Appendix II WSL Legal Mandate). These thematic constraints reflect political decisions regarding the importance of particular topics for Switzerland. In contrast, the scope of the activities of ETH Zurich and EPFL in science and engineering is broader and not subject to any constraints.

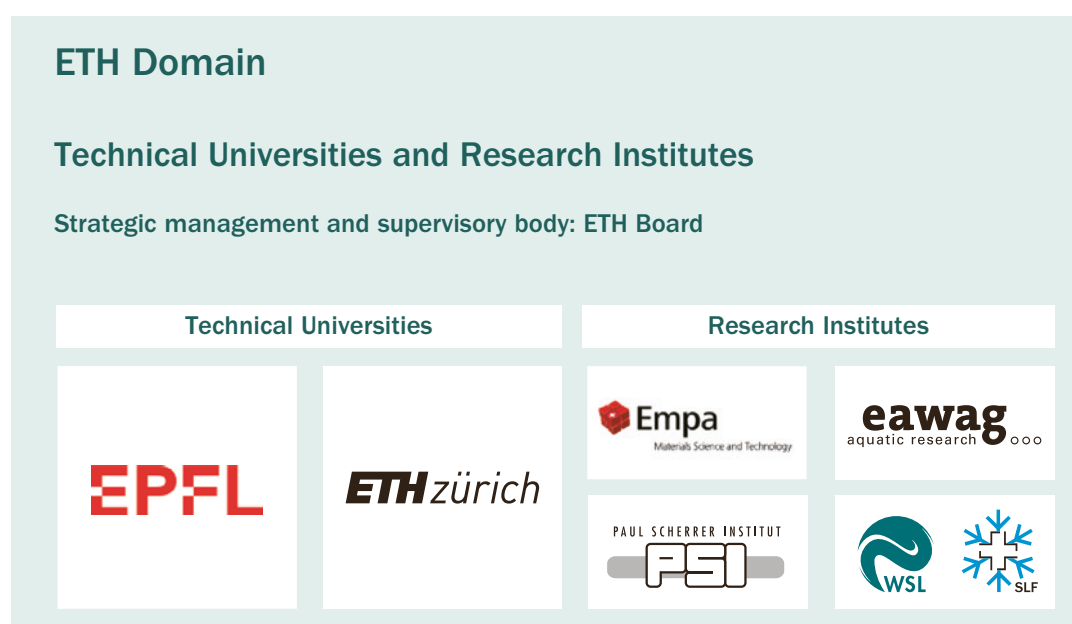


Figure 2.1: The organization of the ETH Domain.

2.3 Position in the Swiss institutional landscape for environmental aspects

WSL plays an active role in environmental science and in the Swiss institutional landscape beyond the ETH Domain, covering basic, practice-oriented and applied research, as well as the translation of scientific results for policy-makers. As the only federal research institute in Switzerland addressing terrestrial environment systems, WSL collaborates closely on environmental topics with other research partners, mostly from academia but also from other federal institutions, such as:

- the Federal Office for the Environment (FOEN), which ensures the sustainable use of natural resources including soil, water, air, quietness and forests. At the federal level, it is responsible for ensuring protection against natural hazards, safeguarding the environment and human health against excessive impacts, and conserving biodiversity and landscape quality. It also coordinates and develops Switzerland's political and strategic positions on international environmental questions and manages international negotiations and processes in this area.
- MeteoSwiss, the Federal Office of Meteorology and Climatology, which provides weather and climate information and operates the national weather measurement network.
- Agroscope, the federal competence center for agricultural research affiliated with the Federal Office for Agriculture (FOAG), which focuses on issues around sustainable agriculture and the food industry.
- SwissTopo, the Federal Office of Topography, which serves as Switzerland's main geoinformation center and is responsible for the collection, management and provision of official geodata and the provision of spatial services.
- other relevant Swiss federal authorities, including the Federal Office for Spatial Development (ARE) and the Federal Office of Energy (SFOE).

WSL also maintains close relationships with the respective cantonal offices for forests, natural hazards, and nature conservation for the purpose of knowledge transfer and issues of practical relevance. Academic partners outside of the ETH Domain include cantonal universities and universities of applied sciences.

2.4 Mandate

WSL's thematic focus is the area of terrestrial environmental research, where it strives for excellent research, knowledge transfer and application in practice, and outreach to society and politics. This largely reflects the legal framework in which WSL operates (see Appendix II WSL Legal Mandate)

WSL is legally mandated to cover the field of sustainable spatial development, in particular in mountainous regions and densely populated areas, and to address the thematic areas landscape, forest ecology and management, natural hazards – including avalanches – and integral risk management, and snow, ice and permafrost. Biodiversity and water resources, while not explicitly listed, are implicitly included in these areas.

In addition, WSL is mandated by federal legislation to fulfill a range of tasks (see Appendix II WSL Legal Mandate):

1. Running the Swiss National Forest Inventory, the monitoring of Swiss Natural Forest Reserves, and the Long-term Forest Ecosystem Research program:

In collaboration with FOEN, WSL collects and analyzes fundamental data on the status of and changes in Swiss forests with the Swiss National Forest Inventory (NFI) and monitors the long-term development of Swiss Natural Forest Reserves. In addition, WSL investigates how Swiss forests respond to changing environmental conditions through the Long-term Forest Ecosystem Research program (LWF).

2. Providing the avalanche warning service for Switzerland and informing the public about avalanche danger:

The WSL Institute for Snow and Avalanche Research SLF provides the avalanche warning service for Switzerland and informs the public about avalanche danger, in particular through regular reporting (avalanche bulletin) or through the mobile app White Risk, which is widely used across Switzerland.

3. Running the Swiss Forest Health Service:

WSL organizes, together with the cantonal forestry services, the collection of data of relevance for forest protection, it provides information about the occurrence of pests and pathogens that may damage forests, and it advises the cantonal forestry services on matters of forest protection.

4. Providing scientific and technical support for the health of forest plants:

Regarding the protection of plants against particularly dangerous and harmful organisms, WSL is responsible for the scientific and technical aspects of plant health in the forest sector. Together with FOAG and its federal agricultural research institutes, WSL ensures that authorized plant protection products, when applied according to regulations, do not have any adverse effects on humans, animals or the environment.

Related to these tasks legally mandated by the Confederation, WSL is involved in several important national initiatives and committees. These include membership in the Federal Civil Protection Crisis Management Board (BSTB); participation in the Steering Committee for Intervention in Natural Hazards (LAINAT); involvement in the Swiss Federal Plant Protection Service (SPPS); and membership in the Swiss National Centre for Climate Services (NCCS), which coordinates the development and propagation of climate services.

WSL provides several additional services in close collaboration with the responsible federal authorities. These include services where synergies with WSL's research activities or mandates exist, such as: managing the Swiss forest fire database Swissfire, which is mandated by FOEN and is conducted in collaboration with cantonal forest services; monitoring the effectiveness of habitat conservation in Switzerland in nationally important habitats; contributing to national cryosphere monitoring in the framework of the Global Climate Observing System (GCOS) Switzerland for snow, glaciers and permafrost; maintaining an operational snow-hydrological service, which includes continuous analysis of the spatial and temporal distribution of snow water resources in Switzerland, thereby facilitating improved hydrological forecasting and timely regulation of water resources; assessing the relationship of the Swiss population with the forest through the Sociocultural Forest Monitoring program WaMos; managing the Datacenter Nature and Landscape (DNL); managing two national centers for species data and information, SwissLichens and SwissFungi, which compile and process information on the distribution and ecology of Swiss lichens and fungi; and operating the WSL plant protection laboratory, which includes a quarantine safety greenhouse.

Fulfilling the above mandates and tasks requires up-to-date, high-quality scientific facilities and infrastructure, excellent levels of scientific and technical expertise, and vast experience in combining research and application for the needs of practitioners. As a federal

research institute within the ETH Domain, WSL is well placed to deliver and continuously enhance such national services based on sound science and to provide them in the long term.

2.5 Strategic planning of the ETH Domain

The strategic planning of WSL is embedded in the *overarching strategic planning of the ETH Domain* (see Appendix II WSL Legal Mandate). The Swiss Federal Council assigns the ETH Domain strategic goals that are renewed every four years. The ETH Board formulates the ETH Domain's strategy for a planning period, in dialogue with the institutions of the ETH Domain, and supervises its implementation. The strategic plan is the central tool of the ETH Domain's strategy and is thus essential for defining the key areas in teaching, research and knowledge transfer, for establishing science policy objectives, and for determining prioritized large-scale projects for the ETH Domain. The strategic plan also provides information about the resources required and serves as a basis for development plans of the institutions of the ETH Domain.

In its Strategic Plan 2021–2024, the ETH Board decided to maintain the focus on three Strategic Areas – Personalized Health and Related Technologies, Data Science, and Advanced Manufacturing.

Work on the Strategic Plan 2025–2028 has begun, and the ETH Board has already defined its Strategic Areas for the new period. The Strategic Areas, besides fundamental discovery science, are topics of particular societal importance where the institutions of the ETH Domain can have a major impact, individually and in cooperation. The Strategic Areas for the ETH Domain in 2025–2028 are: (1) Human Health, (2) Responsible Digital Transformation, and (3) Advanced Materials and Key Technologies. Two new planned Strategic Areas are: (4) Energy, Climate and Sustainable Environment and (5) Engagement and Dialogue with Society (Figure 2.2).

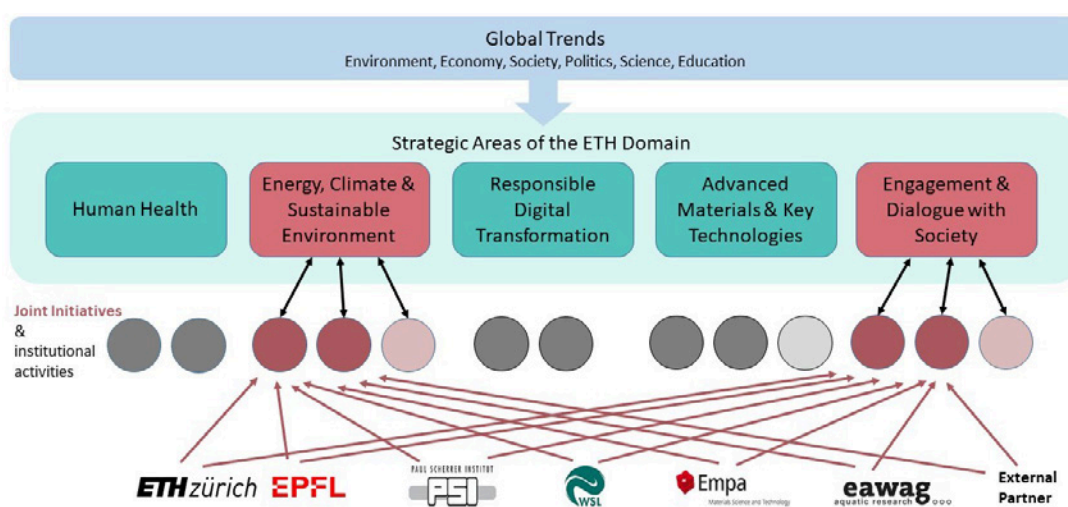


Figure 2.2: By addressing the challenges associated with global trends in environment, economy and society, the five Strategic Areas of the ETH Domain for the period 2025–2028 aim to create a sustainable impact through activities at the six institutions and through strategic collaborative Joint Initiatives between institutions. Source: ETH Board; <https://www.psi.ch/en/strategic-areas-eth-domain/call-jointinitiatives-jan2022>

Joint Initiatives are large, time-limited, strategic collaborative initiatives in one or more Strategic Area of the ETH Domain. Following a call for projects in 2022, the Joint Initiatives for Energy, Climate and Sustainable Environment and for Engagement and Dialogue with Society will start in 2023.

In addition, a number of activities have been launched at the level of the four research institutes in an initiative called ENRICH. With this initiative, cooperation between the four research institutes of the ETH Domain in selected fields (science, administration and education) is being strengthened in a targeted manner. Examples include sensor technologies and applications, activities for sustainable campus development, and Lead Campus, a project aimed at joint internal and external advanced training courses for the staff of the four research institutes. Opportunities to strengthen the coordination of science support services between the research institutes are considered as part of regular operations.

Finally, the ETH Domain has assumed a leading role in adopting the emerging open science practices that allow scientific research outputs – including publications, data and software – to be disseminated and made accessible. For example, the institutions of the ETH Domain have promoted a pragmatic approach towards Open Research Data (ORD) in Switzerland by investing in an ORD program set to run from 2021 to 2024. Information on WSL's performance in the area of open science can be found in Section 6.1.

2.6 Strategic planning of WSL

In keeping with their autonomous status, the ETH Domain's institutions periodically prepare individual development plans and target agreements. These are subject to the approval of the ETH Board, which ensures coordination and harmonization with the strategic goals assigned by the Confederation and the strategic planning of the ETH Domain (see Appendix II WSL Legal Mandate). The WSL development plan and the target agreement for the planning period 2021–2024 guide the institute's activities and form the basis for the information provided in Volumes 1 and 2 of this SAR.

To prepare the WSL development plan for the period 2021–2024, the WSL Directorate initiated a WSL-wide strategy process in early 2019, involving all research units and research programs. The process also covered personnel and infrastructure planning. Important elements of the development plan are strategies to strengthen WSL's research and monitoring activities in and across its five core thematic areas, new strategic initiatives initiated by the Directorate, and responses to ETH Domain strategic planning.

WSL's development plan for 2021–2024 includes the initiation of three new strategic research initiatives as core elements of the institute's strategic planning:

1. the Blue-Green Biodiversity Research Initiative (BGB), intended to strengthen joint aquatic (blue) and terrestrial (green) biodiversity research and outreach and to increase the visibility of WSL and Eawag
2. Extremes, a targeted research program on environmental extremes
3. establishment of the Climate Change, Extremes and Natural Hazards in Alpine Regions Research Centre (CERC) in Davos, focusing on climate change impacts on natural hazards in mountain regions, in collaboration with ETH Zurich and Canton Grisons

The three strategic initiatives are all cross-disciplinary activities, cutting across topics and WSL organizational units. More details can be found in the following sections of this SAR Volume 1.

The development plan also addresses WSL's contributions to the Strategic Areas of the ETH Board for the entire ETH Domain. Moreover, it considers the goals and actions according to the strategic development goals for the ETH Domain in 2021–2024 set by the Federal Council. This includes aspects related to research and research infrastructure, finance, and real estate planning, as well as teaching, knowledge and technology transfer (KTT), national and international positioning and cooperation, role in society, working conditions, equal opportunity issues, and career planning.

Finally, the target agreement between the ETH Board and WSL is based on the WSL's development plan and thus is aligned with the ETH Board's strategic planning for the ETH Domain and the Federal Council's strategic targets for the ETH Domain. The WSL target agreement focuses on selected, strategically relevant projects, programs and plans scheduled by WSL for the period 2021–2024. Reporting for the targets set out in the agreement is achieved via a periodic process, which includes dialogue meetings with the ETH Board and written reports, both on an annual basis.

3 Organization and Management of WSL

WSL is currently organized into twelve research units, six support units and one directorate with its support office. Additionally, seven programs and three centers have been established as crosscutting structures to maximize synergies in WSL's research in a targeted way, to address new emerging questions in an agile manner, and to promote internal and external networking and knowledge transfer. Figure 3.1 is a conceptual view of how WSL is organized, showing the interplay between organizational units, programs and centers around the five core thematic areas of WSL (Section 5). Figure 3.2 shows the concrete organizational chart of WSL. SAR Volume 2 contains a short description of each WSL organizational unit, along with facts and figures including those related to personnel and finance.

Reference to ToRs:

I. Overarching questions
(4) Dynamics

II. Specific questions
Institutional level (a)

3.1 Research units and groups – the foundation of WSL's research activities

From an organizational point of view, WSL has 12 research units that are generally set up around topics or disciplines and further subdivided into research groups. From a functional perspective, the research units work in close cooperation with each other and contribute together to projects, programs and centers to different degrees (Section 3.2). The size of the research units usually varies between 30 and 50 full-time employee equivalents (FTE), and the units each include 3 to 6 research groups. Three research units are smaller (17–25 FTE). Many projects and activities are linked to more than one of the five thematic areas. Societal, political and economic aspects are also included in many projects, in close collaboration with the research unit Economics and Social Sciences, which works on its own research projects while also giving necessary input on various inter- and transdisciplinary projects and activities within the other research units. Because of the different weights of the thematic areas, the research units are not organized around them. The structure of the research units is occasionally revised. All research units are directly subordinated to the Director.

The 12 research units include a total of 51 research groups, generally consisting of 5 to 10 employees and a variable number of students, trainees and short-term employees. The groups focus on specific topics or methods or incorporate specific large projects, such as those funded by the European Research Council (ERC). The Directorate decides which research groups are established or dissolved and how they are organizationally embedded in research units.

3.2 Programs and centers – means to bundle activities across WSL (and beyond)

WSL has several means to bundle activities across the institute, with the most important being programs and centers. Under ongoing climate change, biodiversity loss, dynamic socio-economic developments, and globalization, new research questions are emerging and need to be addressed adequately and in an agile manner. In many cases, these questions should be studied by multi-disciplinary teams that change in composition and expertise from question to question. At the same time, fundamental knowledge and key background information on the functioning of natural and social systems and on their long-term development, as assessed in long-term monitoring activities, for example, are required to tackle these new questions. Therefore, it is essential for an institution like WSL to be able to combine and balance agile responses to new topics and questions with continuity of

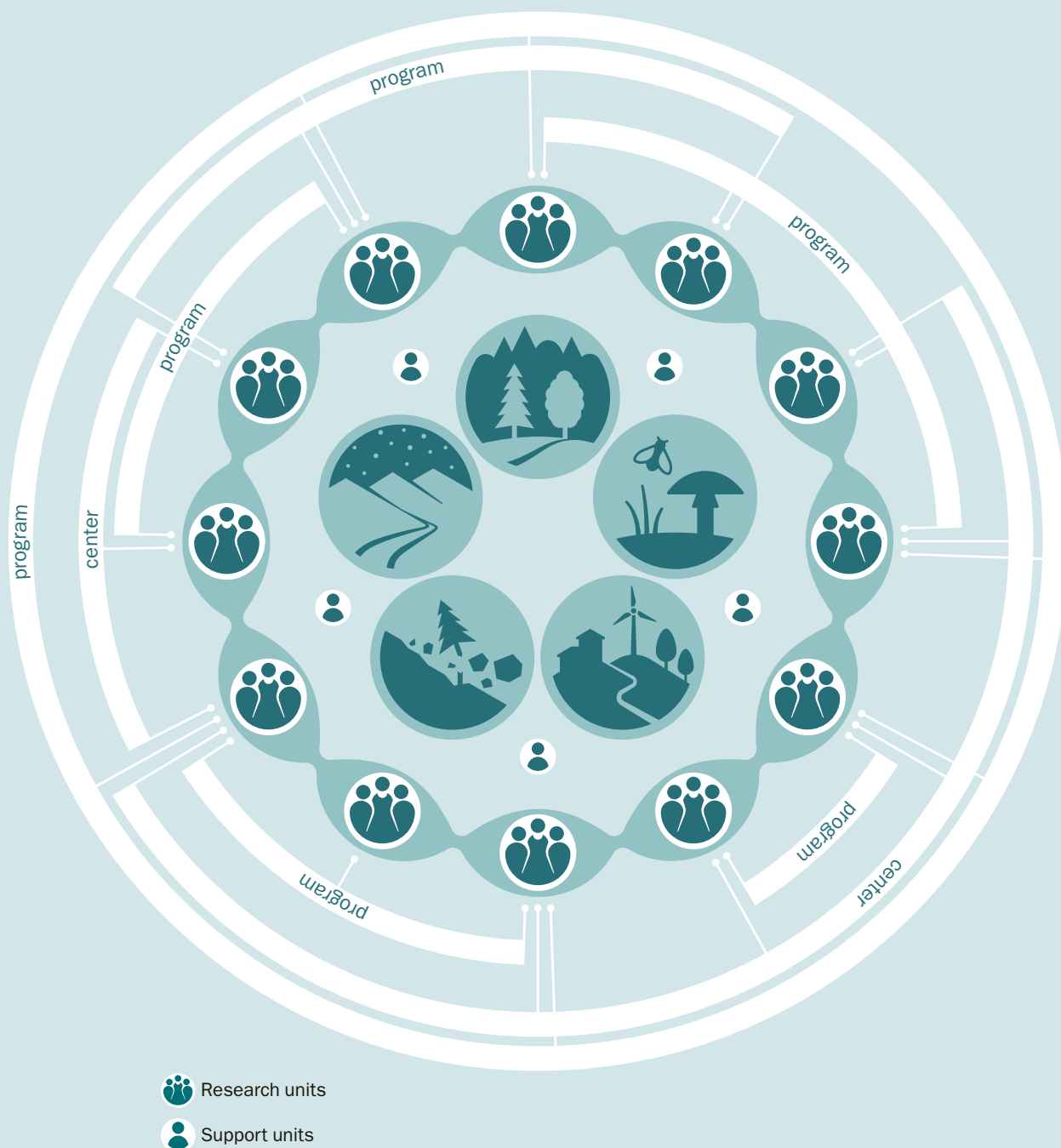


Figure 3.1: Conceptual view of how WSL is organized (the number of units, programs and centers is not representative). The **five core thematic areas** of WSL are forest, biodiversity, landscape, natural hazards, and snow and ice (Section 5). **Research units** are structured according to the disciplines they cover, and they address one or several thematic areas of WSL. **Support units** provide technical services and infrastructure to WSL. **Programs** address relevant topics in an interdisciplinary manner across the institution. **Centers** are platforms pooling knowledge from across WSL and providing interfaces with stakeholders and practitioners. Programs and centers are fed by the scientific contributions of the research units.

Organizational chart

Directorate

Director

Prof. Dr. Beate Jessel

Deputy Director

Dr. Christoph Hegg

Members

Prof. h.c. Dr. Anna Hersperger
Prof. Dr. Rolf Holderegger
Birgit Ottmer
Prof. Dr. Jürg Schweizer
Dr. Thomas Wohlgemuth

Communication

Birgit Ottmer

Directorate Support

Research Units

Prof. Dr. Beate Jessel

Planning and Logistics

Dr. Christoph Hegg

Forest Resources and Management Dr. Marco Ferretti	Land Change Science Prof. Dr. Matthias Bürgi	Human Resources Susanne Jost
Forest Dynamics Dr. Thomas Wohlgemuth a.i.	Economics and Social Sciences Prof. Dr. Irmi Seidl	Finances and Support Ludwig Stecher
Forest Soils and Biogeochemistry Dr. Ivano Brunner	Mountain Hydrology and Mass Movements Dr. Manfred Stähli	Computer and IT Services Stephan Röthlisberger
Forest Health and Biotic Interactions Dr. Eckehard G. Brockerhoff	Alpine Environment and Natural Hazards Dr. Nadine Salzmann	Management of Facilities Birmensdorf Herbert Kurmann
Community Ecology Dr. Marco Conedera	Snow Avalanches and Prevention Prof. Dr. Jürg Schweizer	Management of Facilities Davos Marco Collet
Biodiversity and Conservation Biology Prof. Dr. Rolf Holderegger	Snow and Atmosphere Dr. Martin Schneebeli	Lib4RI: Library Eawag, Empa, PSI, WSL Dr. Lothar Nunnenmacher

Programs and Centers

SwissForestLab

Prof. Dr. Arthur Gessler

Extremes

Prof. Dr. Niklaus Zimmermann

Long-term Forest Ecosystem Research LWF

Prof. Dr. Arthur Gessler

Climate Change, Extremes and Natural Hazards in Alpine Regions Research Centre CERC

Dr. Peter Bebi

Climate Change Impacts on Alpine Mass Movements

Dr. Michael Bründl

Blue-Green Biodiversity

Prof. Catherine Graham

WSL Biodiversity Center

Prof. Dr. Catherine Graham

EnviDat

Dr. Gian-Kasper Plattner

National Forest

Inventory NFI

Martin Hägeli

WSL Landscape Centre

Dr. Silvia Tobias

Locations

Birmensdorf Headquarters	Davos, SLF Prof. Dr. Jürg Schweizer	Lausanne Prof. Dr. Charlotte Grossiord	Cadenazzo Dr. Marco Conedera	Sion Dr. Pierre Huguenin
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Figure 3.2: WSL organizational chart (01.10.2022).

competences and experience. To ensure continuity, WSL is organized into research units and groups (Section 3.1). For agility and to study important emerging questions, WSL launches programs across the institution to bundle competences, combining them with those of partner institutions where appropriate. Programs are generally set up on a temporary basis, lasting about four to eight years.

Currently, seven programs are running at WSL. Three programs were launched as part of the 2017–2020 strategic planning period and will continue until 2024:

1. the Swiss forest research and infrastructure network SwissForestLab
2. the Environmental Data Portal (EnviDat)
3. the research program Climate Change Impacts on Alpine Mass Movements (CCAMM)

Two further programs have been launched for the current planning period 2021–2024 (Section 2.6):

4. Extremes, a targeted research program on environmental extremes
5. the Blue-Green Biodiversity Research Initiative (BGB), which strengthens aquatic (blue) and terrestrial (green) biodiversity research in the ETH Domain and is supported by the ETH Board

Two long-term monitoring programs related to national tasks mandated by the Confederation (Section 2.4) bundle activities from different research units. In contrast to the above-mentioned programs with a duration of four to eight years, they have a longer perspective:

6. the National Forest Inventory (NFI)
7. the Long-term Forest Ecosystem Research program (LWF)

Many of the currently running programs with a limited duration will come to an end towards 2024. EnviDat will be integrated into the normal operations of WSL, the research questions of CCAMM will be further evaluated as part of CERC, and SwissForestLab will be continued as a self-financed activity of all involved institutions. For Extremes and BGB, prolongations are possible, but this will depend on the available financial resources and the priorities to be defined by the Directorate.

Centers also bundle competences across research units and groups. In contrast to the programs, they foster thematic networking within WSL and externally towards specific stakeholder groups with a longer time perspective than programs. WSL currently has three centers:

1. the Landscape Centre established in 2012
2. the Biodiversity Center established in 2020
3. the Climate Change, Extremes and Natural Hazards in Alpine Regions Research Centre (CERC) at SLF in Davos, established in 2021

CERC benefits from substantial financial support of CHF 2 million per year from Canton Grisons and from a collaboration with ETH Zurich. As a result, CERC differs from the other centers in that it not only fosters networking and knowledge transfer, but also hosts timely and relevant research on climate change impacts on natural hazards in mountain regions, in close consultation with Canton Grisons, as explained in SAR Volume 2.

Programs and centers are created according to decisions of the Directorate and require a defined mandate, budget and time horizon, generally based on a proposal prepared within

WSL. Centers and programs are directly subordinated to the Directorate. The position of program or center head is an additional function covered by a scientist already employed at WSL (e.g., head of a group or senior scientist).

3.3 Support units – backbone of WSL

The main support and services for WSL are covered by the six support units: (1) Communication, (2) Human Resources, (3) Finances and Support, (4) Computer and IT Services, (5) Management of Facilities Birmensdorf, and (6) Management of Facilities Davos. The Communication support unit is directly subordinated to the Director for its specific role. The other units are bundled into the planning and logistics domain led by the Deputy Director. The library, a central service for any research institution, is jointly operated as Lib4RI with the three other research institutes of the ETH Domain.

3.4 WSL management

The WSL organizational regulations (“Organisationsreglement” in German) determine the WSL structure, the duties and powers of management members, staff participation in decision processes, and the management handbook. The WSL Director carries the overall responsibility for WSL and is accountable to the ETH Board for the management of the organization. WSL Director Prof. Dr. Beate Jessel was appointed by the Federal Council and started her position at WSL in September 2021. Her role as WSL Director also includes two full professorships at ETH Zurich and EPFL. Beate Jessel succeeded Konrad Steffen, who tragically passed away in Greenland in August 2020. The Deputy Director heads the planning and logistics domain and represents the Director in her absence. Together, the Director and Deputy Director form the Executive Board (“Geschäftsleitung”), which is responsible for the operational management of WSL.

The WSL Directorate includes the Director, the Deputy Director, and five members from research and support units. These five members bring their thematic experience to the Directorate and ensure that a range of perspectives is considered in the decisions of the Directorate. The Directorate determines the strategic orientation of WSL, makes strategic decisions, and supports the Director in managing WSL. Among other tasks, the Directorate makes decisions about the WSL budget, permanent positions, large investments, internal projects and the organizational structure of WSL.

The Office of the Directorate (or Directorate support) supports the Executive Board and the Directorate in conceptual, scientific and operational matters. It additionally provides expertise on institutional matters, such as environment and safety, workplace diversity, inclusion and equal opportunities, scientific controlling, research grant administration, and scientific integrity.

Eight boards and committees support the Director and the Directorate in strategic and operational matters:

1. The Advisory Board provides advice to the WSL Directorate on strategically important issues by providing an outside perspective. The Board is composed of 11 national and international experts from research, practice and politics. As a rule, the WSL Advisory Board meets every one or two years for a couple of days. The last meeting took place in Davos on 21–22 June 2022 (see Appendix III Advisory Board).

2. The Senior Scientists Committee reviews applications for the promotion of staff to the position of senior scientist and makes recommendations to the Directorate. It consists of six senior scientists.
3. The Research Committee (FoKo) evaluates proposals for internal innovative projects and large investments to support the WSL Directorate in decision-making. It consists of seven scientists from research units and one member of the Office of the Directorate.
4. The Laboratory Committee supports the WSL Directorate in decision-making concerning the operation of WSL's laboratories, especially in the case of major investments. It consists of six members from research and support units.
5. The IT Committee (WIKOM) supports the Directorate in decisions about cross-unit and strategic matters in information technologies. It consists of 10 members from research and support units.
6. The Environmental Group supports the Environmental Officer and the Directorate regarding WSL's corporate environmental sustainability, i.e., the planning and implementation of various environmental projects and their communication. It consists of nine people from various research and support units.
7. The Staff Committee (PV) ensures that employees at WSL have a voice. The PV represents the interests of WSL employees vis-à-vis the Directorate and maintains regular exchange with the Director. It consists of nine WSL employees, which are elected by the WSL community every two years.
8. The Crisis Management Team is only activated for emergency and crisis management. From February 2020 until March 2022, it operated as a pandemic management team and was responsible for implementing the requirements of the federal government and Cantons with regard to COVID-19 and guiding the institution through the pandemic. A new crisis management team was formed in autumn 2022 to implement requirements from the government to reduce energy consumption during the emerging energy crisis and to support the institution during this period.

In the "WSL conference" meetings, the senior management of WSL – including unit and program heads, center leads and joint professors – discusses important aspects of collaboration and strategic topics at WSL. The conference serves as a central platform for information exchange.

3.5 Guiding thematic developments at WSL

WSL guides its thematic development through the subtle interplay between the autonomy of research units, the annual calls of the Directorate, and the establishment of programs (Section 3.2). The decision-making mechanisms driving research priorities in the mid- and long term at WSL require regular interactions between the Directorate, research units and individual researchers. Researchers play a key role, as they have in-depth knowledge in their fields of expertise and are able to identify knowledge gaps, anticipate opportunities for scientific developments, and identify issues before problems arise. During the process of strategic planning resulting in WSL's development plan (Section 2.6), the Directorate interacts with the research units and programs to establish the most promising scientific directions and the needs of personnel and infrastructure to implement their strategies.

At the institutional level, the autonomy of WSL's research units in defining their research foci in the framework of their strategy and mandates (e.g., tasks mandated by the Confederation) must be balanced with the centralized management of resources. To achieve this balance, the Directorate allocates annual budgets to research units for their expenses and offers additional financial resources through open competition (e.g., an annual call

for permanent positions) to reach strategic objectives. Support units receive the resources necessary to conduct their tasks efficiently, in agreement with compliance rules. Each unit has a number of members employed with permanent contracts and an annual budget for material expenses.

An annual competitive call for permanent positions is a key element guiding WSL's thematic development. Every vacant permanent position falls back to the Directorate and needs to be requested again with a sound justification and profile. In this way, the recruitment of long-term personnel plays an important role in defining the core competences of WSL in the long term. Therefore, for the replacement of permanent positions or the creation of new or modified ones, the requests are, as far as possible, pooled in the annual call for permanent positions and evaluated by the Directorate. In this call, requests for new permanent positions compete with proposals to fill vacant positions. The Directorate decides which positions will be filled, based on WSL's development plan (Section 2.6), the strategies of the research units, the quality of the proposals, and of course the available resources. In contrast to permanent positions, fixed-term positions in the research units are generally paid by third-party funding for time-limited projects. Projects funded by third parties are aligned with WSL's strategy.

Annual competitive internal calls launched by the Directorate for innovative projects and major investments are additional important tools used to steer WSL in the short and mid-term. The internal call for innovative projects aims to promote innovation in research and implementation/application in a flexible way. This call supports projects (up to CHF 60,000, usually corresponding to a 6-month duration) that could not be funded by other channels. Between 2017 and 2021, WSL invested about CHF 5.8 million in over 90 internal projects. A separate internal call for major investments exceeding CHF 50,000 allows WSL to support infrastructure (e.g., equipment, instruments) to keep the existing technology up to date or to explore emerging technologies. For instance, a new *environmental DNA (eDNA) lab* was established thanks to this call (Section 4.3). The Research Committee and the Laboratory Committee support the Directorate in evaluating the proposals (Section 3.4).

It is essential for WSL to rapidly and unbureaucratically support research activities that have immediate relevance for practice and society. For instance, in autumn 2018, the Directorate funded the *Drought Initiative 2018*, which was proposed by several research units to assess the impact of the severe 2018 drought in a holistic way based on the multiple core competences of WSL in the fields of forests, hydrology and biology. With this financial support, WSL scientists were able to start the assessment rapidly and to already provide some first results on the impact of the 2018 drought by the summer of 2019.

In summary, the steering of WSL aims to ensure long-term expertise in WSL's research units and crosscutting research in its programs, while also rendering the institution flexible and agile to address newly emerging research questions and give the research units the necessary space to express their creativity and explore new ideas.

4 Personnel, Finance, Infrastructure and Communication

To fulfill its various duties in the areas of research, knowledge transfer/application, and outreach to society and politics, WSL relies on its personnel, financial resources, infrastructure and communication expertise. WSL adopts best practices in scientific integrity, promotes equal opportunity and workplace diversity, and operates in an environmentally sustainable manner.

4.1 Personnel

WSL's greatest asset is its committed and enthusiastic staff, who make it possible for WSL to address a large range of topics and crosscutting issues and to respond competently to emerging issues of scientific and societal relevance.

4.1.1 Current development

Since 2017, WSL has experienced personnel growth of 16% (see Appendix I Facts and Figures). This increase is mainly explained by the start of several large initiatives (e.g., establishment of CERC, the new research programs Extremes and Blue-Green Biodiversity, and three European Research Council [ERC] projects), which were funded by various sources (e.g., WSL, ETH Board, Canton Grisons, European Commission).

WSL is entering a period in which numerous retirements are due, including staff with strong expertise in knowledge transfer and outreach. In terms of recruitment, WSL therefore faces the challenge of maintaining an excellent portfolio covering basic and applied research, knowledge transfer, and outreach. In parallel, workplace diversity and equal opportunity should be further fostered at WSL. To incorporate these various aspects into the hiring process, all technical and scientific positions for longer than one year must be recruited with gender-parity search committees. In addition, for each retirement or replacement of a permanent position, the WSL Directorate conducts a job analysis and reviews the profile and scientific orientation, taking WSL's strategy and financial resources into account.

4.1.2 Personnel policy

A mixed composition of scientific and technical staff employed with permanent and fixed-term contracts enables WSL to maintain both long-term expertise and flexibility for time-limited research projects. WSL therefore strives to maintain a one-to-one ratio between employees with permanent contracts and those with fixed-term contracts. At the end of 2021, 51% of the personnel (in full-time equivalents, FTE) held fixed-term contracts, mainly in the scientific staff (see Appendix I Facts and Figures).

WSL fosters an inspiring and motivating work environment based on the principles of trust, respect, equal opportunity and dialogue, where qualified employees can fully use and advance their skills and knowledge. Working conditions at WSL support flexible forms of work and facilitate reconciliation of career and family, helping the institution to remain competitive and attractive as an employer.

WSL supports the lifelong learning of its employees at all levels and in all functions. In recent years, WSL has actively increased its support for superiors in their leadership responsibilities through mandatory specific training and coaching programs. WSL supports education and training programs both outside and inside WSL.

Reference to ToRs:

I. Overarching questions
(4) Dynamics

II. Specific questions
Institutional level (a)(b)(c)
Long-term research and
monitoring (f)

Overall, WSL is a valued employer, as demonstrated by a recent comprehensive survey in 2022 targeting all WSL employees and asking questions about work satisfaction, work content, collaboration, work climate, internal services, leadership, diversity and inclusion, career, and management. The results show an overall high level of satisfaction and commitment among employees, with the perceptions of women and men being equal in this respect. Based on the results of the survey, WSL is developing appropriate measures for further improvements of job satisfaction.

4.1.3 Equal opportunity, diversity and inclusion

The diversity of staff regarding job description, qualification profile, experience, educational level, age and gender contributes to WSL's success. WSL promotes a culture of mutual respect, in which all employees work together constructively to create a non-discriminatory work environment and to prevent bullying and sexual harassment. As a means of guidance, WSL has laid down its policy in a *Respect Code of Conduct* and regularly conducts awareness campaigns (most recently in 2019 and 2021). In case of infringements of these rules, conflicts or other work-related issues, WSL employees can seek help and support from a broad network of professionals, such as the HR department, the confidential counsellor for WSL (ombudsperson), the line manager and external counselling services.

WSL has a *Diversity and Inclusion (D&I)* representative whose role is to advance societal topics related to diversity and inclusion and to support WSL and its employees in that regard. The D&I representative has, for instance, started to hold an annual meeting with the head of each research or support unit to increase the awareness of D&I issues. Regular activities are also held to increase awareness for LGBTQI+. WSL publishes the monthly Newsletter for Equity, which features news and good practices on D&I issues for three of the research institutes of the ETH Domain. While the focus of activities running at WSL is currently gender equality, preparations are also underway to expand the gender strategy to other diversity dimensions in 2025–2028.

The current Gender Action Plan 2022–2024 aims to ensure equal opportunities at WSL and focuses on measures for women in research (scientific and technical staff) and leadership positions. It presents a large range of measures, in the fields of recruitment, career promotion, creation of sustainable networks, and reconciliation of family and work (Figure 4.1). Several of these measures, especially in the field of life domain balance, are accessible to both men and women. Further, WSL aims to have at least 28% women in management positions by the end of 2024 (currently 24%), while targeting 30%. In addition to measures taken on the recruitment level, WSL is preparing a mentoring program for women wanting to take on managerial responsibility. Several mentoring programs



Figure 4.1: Interacting components of the WSL Gender Action Plan 2022–2024 and overview of measures. © Andrea Benedela

for early-career female scientists (e.g., *Fix the Leaky Pipeline*, *CONNECT* in academia and industry) support them in their personal and career development. The *Women's Peer Mentoring Group*, a group of early-career female scientists on short-term contracts at WSL, was formed in 2019 to support the career development of its members. The participants organize workshops with experts on topics such as self-marketing, leadership skills and grant writing. They reflect on their short- and long-term individual career goals in the group and with their mentors.

4.1.4 Supporting early-career scientists

PhD students and postdocs make a considerable contribution to WSL's research. WSL supports early-career scientists with various measures, such as offering a large number of courses specifically for them, a *PhD Club* that runs workshops and networking events, and a PhD coach for one-on-one consultations. They also have access to the counseling services mentioned in Section 4.1.3.

In 2020 WSL implemented new *guidelines* for PhD students at WSL, which complement the regulations of the universities awarding the degree. The recommendations in these guidelines relate to the overall quality aspects of a PhD. For example, PhD students employed at WSL are supervised by at least two independent people, i.e., one from the university and one from WSL. WSL will continue to extend its measures to support early-career scientists.

Career development and transition planning form an integral part of the annual Management by Objectives (MbO) process and help to ensure transparent communication about possible internal and external career opportunities. The tenure-track approach, which involves the open announcement of permanent research positions at WSL, is designed to maintain transparency regarding long-term opportunities in research. WSL additionally offers career planning workshops for PhD students and postdoc researchers and is currently developing this range of offers further and initiating a joint approach between the four research institutes of the ETH Domain.

As part of the Gender Action Plan 2022–2024, WSL offers family support for postdocs. If these researchers wish to take on childcare responsibilities, they can reduce their level of employment to 60–80% for up to one year and apply for an extension of their position, for a total of 120% maximum (e.g., they can work at 60% for two years rather than 100% for one year).

4.1.5 Scientific integrity

WSL recently published a brochure on integrity in research, presenting guidelines for good scientific practice. It is based on guidelines issued in the ETH Domain and on the recommendations of the Swiss Academies of Arts and Sciences. WSL has an advisory and arbitration board that handles suspected infringements and follows rules of procedure for the investigation into cases of suspected breach of research integrity. No formal investigations or cases were opened or closed between 2017 and 2021.

WSL offers its researchers several training, further education and awareness-raising activities. For instance, in 2018 the focus was on events related to scientific integrity, including information on benefits and the use of plagiarism software. A workshop on ethics and scientific integrity for early-career and experienced scientists took place at WSL in 2021. Currently, WSL is evaluating mandatory online training for new PhD students and postdocs and an in-person workshop on ethics in research offered on a regular basis.

4.2 Finances

WSL is financed by the Confederation (federal financial contribution) and third-party funding from various sources.

4.2.1 Financial situation

The basis for WSL's financial statements is the accounting manual of the ETH Domain, in accordance with International Public Sector Accounting Standards (IPSAS). The overall operating revenue of WSL (federal financial contribution and funds from third parties) varied between CHF 88 million in 2017 and CHF 90 million in 2021. The federal government's financial contribution was CHF 63.2 million in 2021 (Table 4.1), up from CHF 58.7 million in 2017. This increase of CHF 4.5 million was mainly due to credit deferrals from the ETH Board to WSL for the Blue-Green Biodiversity Research Initiative and to the transfer of the financial contribution to avalanche warning (CHF 2.7 million) from FOEN to WSL's basic budget, funded directly by the Confederation.

Table 4.1: Annual financial contribution from the federal government (2017–2021) in CHF million.

Federal financial contribution	2017	2018	2019	2020	2021
Basic contribution	57.5	57.0	55.0	56.7	53.5
Credit transfers ETH Board		0.0	0.1	1.2	2.6
Transfer avalanche warning					2.7
Investments for buildings	1.2	1.2	2.6	1.4	4.4
Total federal financial contribution	58.7	58.3	57.7	59.4	63.2

In addition to basic funding, WSL acquires third-party funding from: (1) competitive calls (e.g., SNSF, Innosuisse, EU framework programs, foundations), (2) the public sector (e.g., federal offices, cantonal authorities, municipalities) and foundations, and (3) industry. The share of third-party funding increased steadily from 28% in 2017 to 32% in 2020 and then decreased again to 28% in 2021 (Figure 4.2). This decline is explained by the transfer of the financial contribution for avalanche warning from FOEN to WSL's basic budget. Due to the recent successful acquisition of major projects and initiatives (e.g., CERC, three ongoing ERC projects), WSL is optimistic that it will reach about 30% third-party funds

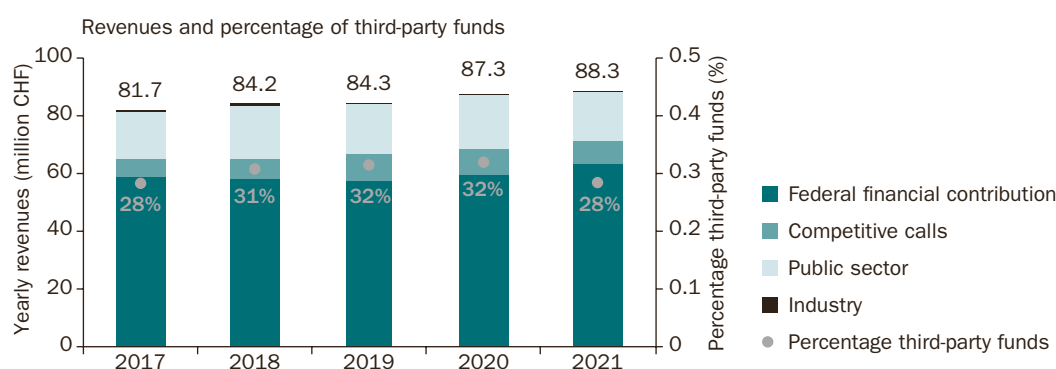


Figure 4.2: Yearly WSL revenues from the federal financial contribution and funding from various third parties from competitive calls (e.g., SNSF, Innosuisse, European Commission), the public sector and foundations (e.g., federal offices, Cantons), and industry.

in the period 2021–2024. Higher percentages will only be feasible if indirect costs are fully covered by external funding sources.

The largest share of costs at WSL is personnel expenses (CHF 72 million in 2021).

4.2.2 Financial strategy

WSL is committed to ensuring the cost-efficient and sustainable use of financial resources. This includes managing the financial reserves in accordance with the Federal Council's mandate and within the framework of the strategic goals of the ETH Domain. To remain flexible, innovative and competitive, WSL maintains its strategic financial investments in innovative projects, programs and research infrastructure. This is achieved by: (1) investing free reserves built up in the past and (2) continuously sunsetting or cutting back research activities where goals have been achieved. In recent years, WSL has used free reserves for new strategic programs (CHF 13.6 million) and for construction. For instance, it has invested around CHF 10 million in a new building in Davos in connection with the establishment of CERC (Figure 4.3).

To secure the financing of personnel expenses in relation to revenues in the long term, WSL has defined an upper limit of 68% of personnel costs financed by the federal contribution. This share was 67% at the end of 2021. Iterative financial planning thus allows WSL to monitor and control its financial situation. Currently, WSL has planned and forecasted annual budgets until 2028. This planning tool shows an overview of expenses, reserves and financial buffer, and can be continuously adapted to reflect future developments.

4.2.3 Financial outlook

For the current planning period 2021–2024, WSL anticipated a yearly increase of 1.5% in basic funding from the federal government until 2024. In the *Strategic Plan 2025–2028* for the ETH Domain, the ETH Board expected – until recently – an annual growth rate of 2.5% in real terms. However, this forecast has now become rather unlikely, in view of



Figure 4.3: New building at SLF in Davos (shown in the foreground). Photo: Y. Bühler, WSL.

the tense financial situation at the Confederation and its large deficits expected for the year 2024. Therefore, the anticipated growth until 2024 is likely to be reduced, and the ETH Board is currently anticipating a growth of 1.5% at best for the period 2025–2028. In this context, WSL remains vigilant about its expenditures, and its financial planning is updated regularly to reflect new developments. New WSL financial commitments and their long-term impact on the institute's finances are thoroughly examined. The financial contribution of WSL (CHF 1.5 million) to the Joint Initiatives “Energy, Climate and Sustainable Environment” and “Engagement and Dialogue with Society” of the ETH Board (Section 2.5) has already been included in WSL's financial planning. In total, eight projects related to these Joint Initiatives have been approved for funding and will start in 2023.

4.3 Infrastructure

WSL's infrastructure includes buildings, research sites, experimental platforms, laboratories, data and digital infrastructure. In Birmensdorf and Davos, WSL is fully responsible for the maintenance and the further development of all buildings, even though the buildings are owned by the Confederation and not by WSL. The total value of the buildings handled by WSL is about CHF 140 million. At the three other sites, the buildings are managed through partners. In Ticino, WSL operates a modern building together with Agroscope (the federal competence center for agricultural research) at the Cadenazzo campus. In Lausanne, the WSL office is part of EPFL, and in Sion it is part of HES-SO Valais-Wallis, a university of applied sciences. At all sites, WSL operates infrastructure not only for its employees but also for its numerous students, guests and trainees. Infrastructure in Birmensdorf, Davos and Cadenazzo also includes simple accommodation for short- to medium-term stays.

WSL operates a comprehensive environmental research network including monitoring sites, experimental platforms and laboratories (Figure 4.4).

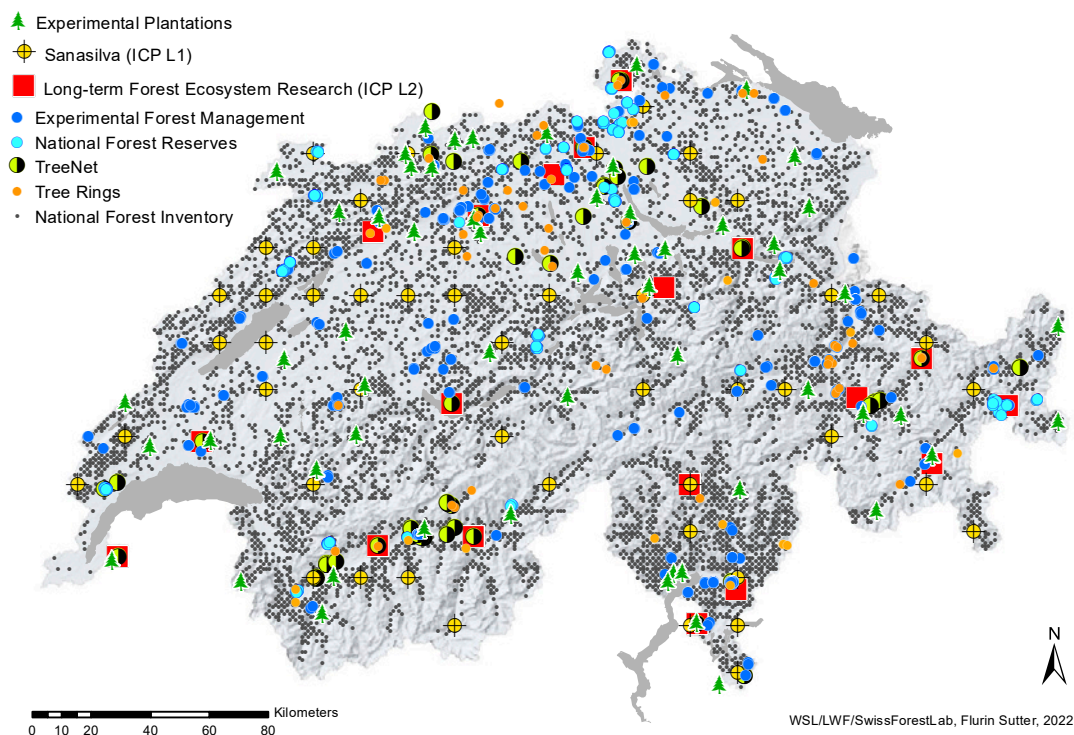


Figure 4.4: Examples of research infrastructure in the thematic area forest (Section 5.2).

More than 6000 sites distributed across Switzerland are operated as part of WSL's many monitoring activities, such as the Swiss National Forest Inventory (NFI), the Long-term Forest Ecosystem Research program (LWF), and the Monitoring the Effectiveness of Habitat Conservation in Switzerland project (WBS). In addition, the study plot on Weissfluhjoch above Davos is SLF's oldest test site, hosting a unique snow data series extending over 80 years. WSL also operates several experimental platforms. Examples of international relevance include the avalanche test site in Vallée de la Sionne, which is used to study avalanche movement (Figure 4.5); the debris flow observation station Illgraben, which is equipped with sensors to investigate the flow behavior of debris flows; the hydrological test site in Alptal, where innovative methods are used to measure sediment transport in streams; and the forest irrigation experiment in Pfynwald, conducted to better understand the long-term effects of drought periods on pine forests. State-of-the-art laboratories are also essential for WSL research. Examples are the plant protection laboratory, one of the few biosafety level-3 laboratories in the world with an integrated greenhouse; the stable isotope laboratory; the tree-ring and wood anatomy laboratory; the new eDNA laboratory; and the cold laboratory at SLF in Davos, comprising facilities for micro-computed tomography and the production of artificial snow identical to natural snow. More details on the *research infrastructure at WSL* are available on the Internet.



Figure 4.5: Observation bunker at the avalanche test site in Vallée de la Sionne in the canton of Valais. Scientists and technicians monitor measurements at the test site from the observation bunker, and radars measure the speed of avalanches. Photo: WSL and M. Hiller, SLF.

To ensure long-term internal and external accessibility to WSL's rich environmental data pool, WSL has launched the program *EnviDat*. In the framework of this program, a data portal has been developed to provide unified and managed access to WSL's collection of long-term environmental monitoring and research data. It also supports scientists in publishing their data by providing digital object identifiers (DOIs) for datasets, making citation easier. *EnviDat* adheres to FAIR principles (findability, accessibility, interoperability and reusability), provides a research data repository, and includes open science support and tools for WSL researchers.

The digital infrastructure of WSL extends from single desktop/laptop computers to large high-performance computing (HPC) clusters and from stand-alone IT programs to integrated web applications with underlying databases. New technologies and trends, such as the Internet of Things, Blockchain, Deep Learning, and artificial intelligence (AI), are standard in many research projects at WSL. In addition, field and lab work are becoming more and more digitized. Therefore, the digital infrastructure of WSL is constantly evolving to meet the challenge of achieving the optimal balance between services provided and related costs and between insourcing and outsourcing.

WSL's digital infrastructure is embedded in the support of the *SWITCH Foundation*, which operates the backbone of the Swiss digital research infrastructure. Where efficiency gains are larger than cooperation costs, digital infrastructure is operated in collaboration with other institutions of the ETH Domain.

4.4 Communication

WSL's objectives and general approach to communication are set out in the *Communication Strategy 2021–2024*. This approach applies not only to the Communication support unit, but also to all staff members in research and support units who are involved in communication activities. WSL's communication strategy distinguishes between four main target groups for communication and thus fields of activity. The first field is knowledge transfer and communication to users and practitioners, by offering them, for example, courses, workshops, excursions and practice-oriented publications. The second is outreach to a large audience, including politicians and political groups, by informing them about exciting projects and publications authored by WSL staff members. Special effort is made to reach people who are less familiar with science and to offer them knowledge that enables them to develop evidence-based perceptions and opinions on environmental topics. In this way, outreach supports the social and political valorization of WSL research. The third is the communication by WSL researchers to the scientific community by publishing articles in scientific journals, as well as giving lectures and poster presentations at scientific conferences. Finally, internal communication to WSL employees involves informing staff members about all activities and decisions related to work at WSL.

To reach these various target groups, WSL uses several communication channels:

Media relations: With approximately 2000 print, radio and TV clippings per year, WSL is very present in the mass media in Switzerland. Despite the decline in importance of the traditional media, media relations are still central in reaching the public and politicians.

Web: In addition to hosting its own institutional, quadrilingual websites www.wsl.ch and www.sl.f.ch, WSL participates in several cooperative websites, such as www.waldwissen.net and www.naturgefahren.ch, and it operates various target-group-specific portals, such as www.whiterisk.ch (for off-piste snow sports enthusiasts), www.wsl-junior.ch (for children) and www.drought.ch (for people interested in drought). WSL's presence in popular social media (Twitter, Facebook, LinkedIn, Instagram, YouTube) is constantly increasing in importance. It is ensured by the Communication support unit and by individual WSL researchers.

Print products: WSL publishes the three series *DIAGONAL – the WSL Magazine*, *Fact Sheet for Practitioners*, and *WSL Reports*. WSL also publishes books, mostly in cooperation with a publishing house (e.g., “Wandern, wo andere forschen” and “How to balance forestry and biodiversity conservation. A view across Europe”). WSL's own series have been published under a Creative Commons business license since 2022. In addition, WSL researchers publish hundreds of articles in scientific and practice-oriented journals each year.

Guided tours, school visits, conferences and exhibitions: Targeted formats allow dialogue and discussion with the broader public and various stakeholders. Science communication in such events is essential to build up credibility, trust and long-term impact. In years not affected by the pandemic, over 3000 people visit SLF or WSL with a guided tour. Events can be offered physically, virtually or as a hybrid.

Finally, WSL staff can benefit from the support of the Communication unit for a large range of services, such as advice, translation and language editing in German, French, Italian and English, layout, web publishing and video production (see SAR Volume 2, Communication support unit).

4.5 Corporate environmental sustainability

WSL strives for the highest standards in corporate environmental sustainability. It is particularly important for WSL to use the available resources carefully, to monitor its environmental impact, and to continuously reduce its ecological footprint. In order to reach these goals, WSL has published an environmental policy and maintains an environmental management system. Targets for energy efficiency and greenhouse gas reduction have been set for 2030 in agreement with the federal climate strategy. Since 2016, WSL has compensated all its not yet avoidable greenhouse gas emissions via emission certificates. An environmental report is published every three years, with short annual data updates in between. WSL generates heat by renewable sources (wood chips, heat pump) and exclusively purchases certified electricity from renewable sources, in addition to using self-produced solar energy (130 MWh/a). WSL has pledged to at least double its production of photovoltaic power by 2030. A mobility strategy to reduce travel-related greenhouse gas emissions (air travel, employee commuting) and an increased focus on environmentally friendly and sustainable food products in the canteens have been recent focal points. Other relevant efforts are the management of paper and water consumption, general waste reduction, and the minimization and proper disposal of hazardous waste. At the WSL site in Birmensdorf, a “near-natural space” certified by the Nature and Economy Foundation accommodates numerous animal and plant species in various habitats. Finally, WSL’s environmental group assists in the planning and implementation of various environmental projects, in data collection, and in communication. An overview of this environmental management is available on the *Internet*.

5 Thematic Areas

5.1 Introduction

All major environmental crises of the Anthropocene, such as land-use change, climate change, biodiversity loss, altered biogeochemical cycles, and aspects of urbanization, as well as their linkages, result in challenges to the terrestrial environment. WSL is mandated to cover these issues in research, knowledge transfer and application in practice, and outreach to society and politics. Thus, WSL's activities are related to global challenges, but their aim is to develop national, regional and local solutions that might be applied by Swiss stakeholders, true to its vision of "research for people and the environment" in Switzerland. The mandate of WSL to focus long term on the terrestrial environment and particularly the five thematic areas forest, biodiversity, landscape, natural hazards, and snow and ice assures continuity, but also makes it possible to address newly emerging challenges within and across these thematic areas (Figure 5.1).

Reference to ToRs:

I. Overarching questions

- (1) Relevance
- (2) Quality
- (3) Productivity
- (4) Dynamics
- (5) Opportunities

II. Specific questions

Institutional level (a)(b)(c)

Strategic focus (d)(e)

Long-term research and monitoring (f)(g)

Education (h)

Stakeholder involvement and role in society (i)



Figure 5.1: Illustration of the core thematic areas of WSL and their embedding in the Swiss landscape. Photo: A. Rigling, WSL.

In the following, brief overviews of the current state of WSL's activities in its five core thematic areas are provided. Many of the activities presented here are, however, strongly inter- and cross-disciplinary. WSL therefore regularly launches, for example, strategic programs (Section 3.2) to bundle activities and expertise across the five thematic areas. The crosscutting and interdisciplinary character of WSL's activities is highlighted in greater detail in the subsequent sections.

5.2 Thematic area: forest

Activities cover national needs regarding: forest ecosystem services and their trade-offs, climate change adaptation, monitoring and diagnostics of pests and pathogens, carbon dynamics and biodiversity in forest soils, the ecology of disturbances and extreme events, the development of decision support systems for adaptive management, and the reconstruction of past environmental conditions through dendroecology. Research addresses a wide range of temporal and spatial scales, covering patterns and processes from seconds to millennia and from cells to ecosystems. WSL is a key partner in Europe-wide networks for forest reporting, such as FOREST EUROPE, the Food and Agriculture Organization of the United Nations (FAO), the European National Forest Inventory Network (ENFIN), and the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests).

5.2.1 Research

The overarching guiding principle for WSL's research in forests is integrated forest management. The aim is thus to help sustain important forest ecosystem processes and services and to support the resilience and adaptive capacity of current and future forests. Key topics include the impacts of climate change on above- and belowground processes in forest soils, invasive biota, plant diseases and pests, the protection potential of forests against natural hazards, the promotion of biodiversity, and the securing and integration of the ecological and societal services that forests potentially provide. Cutting-edge methods are applied, e.g., in remote sensing, stable isotope technology, and molecular biology, as well as in research supported by machine learning and artificial intelligence (AI) in many fields.

WSL operates, at the national level, several unique long-term forest monitoring networks, along with many experimental sites and labs equipped with state-of-the-art instruments. It thus provides excellent research platforms and indispensable databases to evaluate the condition and use of Swiss forests and to improve the understanding of the driving factors and key processes in forest ecosystems. The assessment of forest ecosystem responses to environmental changes, such as those related to climate and to socio-economy, is complex because of the long lifespan of trees, the often highly variable local climatic conditions, the structural heterogeneity across different scales, and the high above- and belowground diversity of forest ecosystems.

Research at WSL in this thematic area thus requires: (1) the combination of long-term monitoring and research, in particular the *National Forest Inventory (NFI)*, the *Long-term Forest Ecosystem Research program (LWF)*, the management of experimental forests, the monitoring of *Swiss Natural Forest Reserves*, and the investigation of paleo-forest dynamics and paleo-climate variability; (2) the integration of data from *laboratory studies* (e.g., dendrochronology lab, stable isotope lab, plant protection lab), *field experiments and assessments* (e.g., *TreeNet*, a biological drought and growth indicator network for Swiss forests); (3) a profound understanding of complex processes and interdependencies among biotic and abiotic influencing factors, for example in the *Pfynwald field experiment* (Figure 5.2) and the *experimental plantation network*; (4) state-of-the-art modeling approaches; and (5) in-depth knowledge about forest engineering and management practices, including socio-economic aspects.

5.2.2 Knowledge transfer and application in practice

WSL has extensive experience in translating forest research outcomes to practice and application in multiple ways, such as outreach publications in native languages, textbooks,



Figure 5.2: Pfywald field experiment site: researchers enclose the top of a pine tree on a 12-meter-tall scaffolding for an experiment investigating the metabolism of trees under drought stress. Photo: G. Pestalozzi, WSL.

apps, interactive webpages, courses, excursions and consulting. The WSL strategic initiative *SwissForestLab* was successfully initiated in 2018, with the aim to bundle the forest expertise across all Swiss research institutions to advance the understanding of the complexity and functioning of forest ecosystems and to promote their sustainable use in the future. In particular, *SwissForestLab*'s science–practice dialogue, which has been regularly and jointly organized with stakeholders, brings together forest experts working in academia, in cantonal forest offices, and in local forest management.

WSL researchers contribute to teaching across all levels of forest education: they frequently contribute to the major Forest and Landscape Management courses at ETH Zurich and to courses in related disciplines at other Swiss universities and abroad. They also engage in teaching at universities of applied science, as well as forestry schools, and offer courses for apprentices in forestry and arboriculture. In addition, WSL regularly hosts and contributes to various international summer schools (e.g., the Nancy-Freiburg-Zurich Forest Research Network [NFZforest.net] *summer school*) addressing forest topics, such as tree-ring research, stable isotopes, environmental monitoring, forest management, forest biodiversity, and natural hazards protection.

5.2.3 Outreach to society and politics

Since 1986, WSL has recorded objective information on forests at the national level in the framework of the NFI. Results are available for Switzerland as a whole and for larger regions and individual cantons. At the national level the representative data serves political, social, economic and research purposes, such as the development of models for tree growth and species distributions. Various surveys and monitoring networks – related to forest health, extreme event resistance and resilience, and diagnostics of forest pests and pathogens – coupled with common garden experiments build a rich basis for international collaborations in forest ecology and management, and in general for outreach activities for various stakeholders. FOEN, as well as all Swiss Cantons, rely on data collected by WSL for decision-making concerning forest policy and practice (e.g., *Waldbericht*). At the Euro-

pean scale, the data is used for reporting on the state and health of forests. WSL scientists actively engage in international research unions and networks, in some cases holding leading positions. Many of WSL's activities include components of applied science, targeting practitioners in Switzerland from the federal to the cantonal and community level, as well as practitioners in forest ownership unions. WSL transfers its rich knowledge via the popular Internet platform *Waldwissen.net*, which has more than 2.5 million users per year.

5.2.4 Future research directions

In the future, WSL will further consolidate its research on forest ecosystems and their management in the context of climate change, resource shortages, biological invasions, and the biodiversity crisis. Research will combine monitoring, experimental, modeling and comparative approaches to best fulfill the national tasks mandated by the federal government, to respond optimally to stakeholder needs, and to maintain a leading position in forest research internationally. With regard to the various experimental and monitoring sites and related WSL activities (see Section 4.3, Figure 4.4), improved coordination and better use of synergies is planned. *SwissAIM* (Advanced Inventorying and Monitoring System for Swiss Forests) is a WSL initiative with the aim to build enhanced, efficient, and more integrated monitoring of Swiss forests based on existing systems (e.g., NFI, LWF). Future research activities will cover several areas of great importance for Switzerland and Europe, including the promotion of vigorous and resilient forests and contributions to a sustainable bioeconomy.

5.3 Thematic area: biodiversity

Activities in this thematic area address the loss of biodiversity across all levels occurring under global change. Ecosystems with high or site-specific biodiversity provide better services and resources to humans, are more resilient to stressors, and add to the quality of human life. Therefore, WSL's main goal is to provide sound scientific information to promote the conservation of biodiversity, explicitly addressing habitat and species loss, land-use change, habitat restoration, eutrophication, invasive species and climate change.

5.3.1 Research

WSL studies all levels of biodiversity (genes, species, interactions and ecosystems), applies long-term monitoring in various ecosystem types, carries out process-oriented experiments in nature, common gardens and laboratories, and implements diverse genomic methods. The focus is on *mountain areas* and *forests*. Comprehensive *eco-evolutionary modeling*, both above and below ground and at different spatial and temporal scales, is used to study changes in biodiversity in response to global change. Recently, WSL invested in the integration of remote sensing techniques (e.g., *assessing effects of forest structure on biodiversity using LiDAR*), automated image analysis (e.g., Deep Learning for species identification; Figure 5.3) and environmental DNA approaches (*new eDNA laboratory*). WSL's research in biodiversity integrates *social and economic aspects*, with the latter also being an important component of the Blue-Green Biodiversity Research Initiative (BGB) of Eawag and WSL.

5.3.2 Knowledge transfer and application in practice

Besides diverse transfer channels, such as publications in national languages in professional journals, applied textbooks, apps, seminars, workshops, courses, and field outings for practitioners, direct exchanges with stakeholders represent an especially important

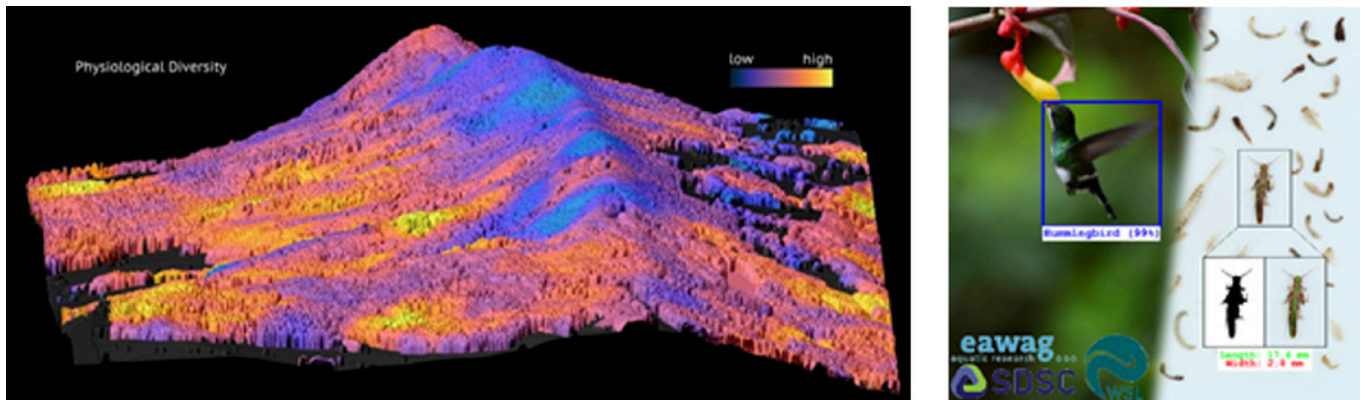


Figure 5.3: Left: Structure of forests (from LiDAR) and their physiological diversity (from remote sensing) at Lägeren (collaboration with University of Zurich). Right: Automated species identification of birds and aquatic invertebrates (collaboration with Swiss Data Science Center [SDSC] and Eawag). Images: F. Morsdorf, L. Pegoraro, WSL.

pathway of knowledge transfer in biodiversity. WSL employees offer a great deal of direct consulting to authorities, non-governmental organizations (NGOs) and private-sector planning offices. For instance, WSL is currently helping Swiss Cantons with the planning of an *ecological infrastructure* for Switzerland.

WSL's research in biodiversity is crucial in enabling practitioners to implement the best strategies and solutions to protect and foster biodiversity in Switzerland and abroad. For example, *research findings are key in guiding action plans and management recommendations for authorities* and in developing *up-to-date monitoring techniques*. Moreover, WSL hosts two national data centers for biodiversity (*SwissFungi* and *SwissLichens*), which are platforms for species conservation in Switzerland. WSL additionally contributes to international and *national Red Lists* for several groups of organisms. A particular focus of knowledge transfer is on *forest biodiversity* and on assessments of the effectiveness of conservation measures (e.g., restoration measures and habitat connectivity or restoration and CO₂ storage in bogs).

University teaching is mainly done in ecology, forest biodiversity, conservation biology, and management and restoration at ETH Zurich and the Universities of Zurich and Bern, as well as in *summer schools*. WSL provides applied aspects, which are often neglected in traditional university teaching but are highly valued by students.

5.3.3 Outreach to society and politics

WSL's research in biodiversity has substantial visibility and impact in society and politics. For instance, WSL is mandated by FOEN to monitor the development of Switzerland's habitats of national importance, such as fens and bogs, dry meadows and pastures, and riparian ecosystems. This data is used directly by federal authorities to steer and finance conservation efforts in four-year planning agreements with the Swiss Cantons. WSL also publishes reports on issues relevant for Swiss politics. A prominent example is WSL's role advising politicians on how to best implement *river restoration* to increase flood prevention and foster biodiversity at the same time. Further, WSL contributes to several of the *official biodiversity indicators* of Switzerland.

WSL scientists engage in many cantonal (e.g., advisory board for Canton Zurich), national (e.g., Swiss Academy of Sciences [SCNAT] Swiss Biodiversity Forum) and international panels (e.g., Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem

Services IPBES) for the conservation of biodiversity. They directly engage with the public by giving presentations, leading excursions and organizing courses and workshops. As the topics of WSL's biodiversity research are of high societal relevance, WSL scientists are often interviewed by mass media on topics such as climate change, biodiversity loss and urban ecology.

5.3.4 Future research directions

In the future, WSL will further explore the interlinkages between biodiversity integrity and climate change, at the interface of two core restrictions within the planetary boundaries framework that defines a safe operating space for humanity. A greater focus will be placed on the connections between biodiversity loss and climate change. This includes – among others – the effects of energy production and infrastructure on biodiversity and how climate change effects can be mitigated by enhancing certain habitats (such as floodplains) or green spaces (as part of biodiversity on an ecosystem level), e.g., in heavily urbanized areas.

Further, WSL's Biodiversity Center will continue to bundle the outcomes of WSL's research activities on biodiversity and to promote internal and external networking, focusing on topics where this is considered particularly relevant or timely, such as eDNA in the current research setting.

5.4 Thematic area: landscape

WSL applies a comprehensive landscape approach that includes rural, alpine and urban spaces, as well as physical and perceived landscape, and is thus in line with the *European Landscape Convention*. This allows WSL to support a wide range of stakeholders and authorities on the path to sustainable development, which is influenced by factors such as urbanization, intensification of land use, loss of biodiversity, climate change, and demand for renewable energy.

5.4.1 Research

WSL's research on landscapes focuses on the interplay of ecological, economic and social aspects and on the complex relationships between people, landscapes and ecosystems. The aim is to understand *how landscapes are changing, which anthropogenic and natural factors are causing these changes, the impacts that can be expected on people and the environment*, and how *strategies for planning and management* can be developed. WSL integrates established and emerging theories from the natural, social and economic sciences to monitor, analyze and model current and historical landscape change and the underlying processes and interactions, including related societal perceptions, expectations and attitudes. With this knowledge, WSL develops decision-making tools and guidelines for evidence-based governance and for the sustainable use and protection of landscapes. Several methods are often combined to address the complex research questions, including remote sensing, spatial analysis, modeling, *quantitative and qualitative surveys*, experiments, participatory (inter- and transdisciplinary) approaches, and content analysis. Data sources include historical archives, earth observations, experiments, surveys, interviews and expert elicitation. The integration of natural and social systems in landscape research at WSL yields, for example, novel contributions in landscape ecology and in the fields of *human health and recreation*, renewable energy, *urban and landscape planning* (Figure 5.4), and *land-change modeling*.

5.4.2 Knowledge transfer and application in practice

WSL's landscape research is highly recognized in practice, both nationally and internationally. In most activities, basic landscape research is strongly linked with knowledge transfer and application in practice. The *co-designing of research* with public entities, including single municipalities but also FOEN and the Federal Office for Spatial Development (ARE), is an especially effective activity in which WSL's landscape research has a long tradition. WSL also routinely supports practice through formal and informal dialogues with stakeholders and through the organization of and contribution to expert workshops. Moreover, WSL is actively engaged in landscape-related (local to international) bodies and institutions relevant to practice, and transfers knowledge via a wide range of *applied publications*. There is a strong focus within WSL on *pooling the widely distributed landscape competences* and building a highly esteemed interface for partners, such as the federal authorities, cantonal and municipal administrations, NGOs, and professional associations. WSL scientists teach landscape topics at the national level through formal engagements at *ETH Zurich*, University of Bern and University of Zurich. WSL covers the majority of landscape teaching in the Department of Environmental Systems Science (USYS) at ETH Zurich.

5.4.3 Outreach to society and politics

In order to reach and inform the public and politicians, WSL's landscape researchers work together with the Communication support unit to regularly present topics on land use and landscape development in a broad range of media, including TV, radio, newspapers and social media. Additional important contributions of WSL to society include activities to raise awareness on timely landscape issues, such as urban sprawl and the impacts of climate change on landscapes. Outreach to politics is pursued through regular discussions with interested individuals and with representatives from many organizations and institutions



Figure 5.4: Cities and urban regions are dynamic systems. WSL investigates the influence of spatial planning on the expansion of settlement areas and the preservation of green areas. Photo: S. Wild, WSL.

and through the engagement of WSL landscape researchers in the science–policy interface (e.g., *SCNAT Forum Landscape, Alps, Parks [FoLAP]*, presided by a WSL member until recently) and in task groups for policy development (e.g., *Swiss Landscape Concept*). Especially relevant in this context is the membership of WSL in the non-parliamentary commissions of the Confederation on spatial planning and on noise abatement, which provide the scientific basis for updates in the Swiss spatial planning and environmental legislation.

5.4.4 Future research directions

In the future, WSL will further focus on systematic land system analysis to address issues of land-change impacts, land-use conflicts, and optimizations for new demands, such as renewable energies. An increasing focus will be placed on questions and needs related to urban and peri-urban landscapes and on people's behaviors and expectations regarding landscapes, with a special focus on health aspects. Strengthening the focus on integrated landscape–water management under the pressures of climate and land-use change is a long-term goal. WSL will take full advantage of novel research data resulting from the application of emerging measurement and monitoring methods and sensor technologies to learn about the interactions between humans, landscapes and ecosystems.

Further, WSL's Landscape Centre will continue to coordinate WSL's activities related to landscape research and encourage networking within and beyond the institute, while also increasing WSL's visibility, mainly towards Swiss stakeholders. It will additionally support the WSL Directorate in considering strategic issues relevant to landscape research.

5.5 Thematic area: natural hazards

WSL's activities in the thematic area of *natural hazards* focus on pursuing a better process understanding of snow avalanches, shallow landslides, rockfall, debris flows, floods and forest fires to protect people and infrastructure from such natural hazards. These hazards cause substantial damage in Switzerland and around the world. In Switzerland alone, the property damage per year from floods and mass movements is estimated at over CHF 300 million, and *23 people are killed on average per year by snow avalanches in Swiss mountains*.

5.5.1 Research

Recent challenges related to the protection against natural hazards include: (1) the increasing effects of climate change on the frequency and extent of mass movements in mountain regions and (2) the consequences of changes in the use of mountainous regions, for example the increasing demand for safe transport and communication infrastructure. Key research questions for WSL are therefore how climate change affects the risks due to natural hazards, what the consequences are for risk management, and, more specifically, how *hazard mapping* procedures need to be adapted in a warming world.

Answering these questions requires sound process-understanding. To this end and in order to improve hazard assessments, protection measures and warning systems, WSL has established several unique experimental sites where processes involved in avalanches, rockfall, debris flows and sediment transport can be studied. These include the avalanche test site in *Vallée de la Sionne*, the debris flow observation station in *Illgraben*, and the torrent test site in *Alptal*.

Recent innovations in WSL's natural hazard research include *data mining of seismic and distributed acoustic signals for the early warning of mass movements*, machine-learning-aided forecasting of (sub)seasonal drought, and development of new instrumentation for assessing permafrost occurrence and thawing.

5.5.2 Knowledge transfer and application in practice

The knowledge, expertise and experience of WSL researchers in natural hazard mitigation is recognized worldwide. WSL regularly supports cantonal authorities and experts with specific analyses and advice in the area of natural hazards and natural hazard mitigation. Some recent examples of major alpine mass movement events in Switzerland where WSL provided expertise include the *Piz Cengalo rockfall in southern Grisons*, the *Spitze Stei instability in the Bernese Oberland*, and the *deep-seated landslide near the village of Brienz in central Grisons*.

The *Climate Change, Extremes and Natural Hazards in Alpine Regions Research Centre (CERC)* was established in January 2021 in Davos, in collaboration with Canton Grisons and with support from ETH Zurich. CERC strengthens WSL's research and knowledge and technology transfer activities regarding the impacts of climate change and extreme events in mountain regions and the ensuing natural hazards. As part of CERC, two new joint professorships with ETH Zurich were recently appointed, which will further enhance WSL's research and teaching activity related to natural hazards and impacts of climate change.

WSL plays an important role in the *continuing education of professionals*, is currently chairing the main association of Swiss experts on natural hazards (*Fachleute Naturgefahren Schweiz*), and holds a lead position in the *national avalanche core training team*. WSL also contributes substantially to the new Certificate of Advanced Studies (CAS) continuing education course on *natural hazard risk management* and to various lectures on natural hazards organized by ETH Zurich.

The most widely used avalanche modeling system worldwide is the *Rapid Mass Movements Simulation software suite (RAMMS)* developed at SLF. Building on its vast capabilities, models for other mass movements, such as rockfall and debris flows, have been developed to support practitioners in analyzing and assessing risks from natural hazards (Figure 5.5). Recent developments facilitate *hazard indication mapping* at the mountain-range scale for present and future climate scenarios. These maps are in high demand by natural hazard authorities and railway companies in Switzerland's mountainous cantons, as well as in many other mountain regions worldwide.

5.5.3 Outreach to society and politics

SLF provides the *avalanche warning service* for Switzerland and informs the public about avalanche danger as a legally mandated national task. This service includes the issuing of the well-known avalanche bulletin twice a day during winter. WSL's involvement in natural hazard warning and prevention systems extends to providing crucial support to federal and cantonal authorities in avalanche and *flood prediction*. Moreover, WSL researchers are leaders in drought forecasting, exemplified by the web-based information platform *drought.ch*. *Mountain forests*, with their protective role against snow avalanches, shallow landslides and rockfall, represent the backbone of natural hazards management in Switzerland. WSL researchers in forest engineering and natural hazards collaborate closely to study interactions between *mass movements and forests*. In addition, mandated by FOEN, WSL manages the Swiss forest fire database *Swissfire*, in collaboration with the



Figure 5.5: The RAMMS software can be used, for example, to investigate the risk of avalanche damage in an area. Photo: S. Margreth, WSL.

cantonal forest services, and has developed the software Fire-Niche, a statistical forecasting tool for assessing the risk of *forest fires*.

WSL engineers provide consulting services to local and cantonal authorities on all natural hazard mitigation strategies. WSL additionally supports the federal authorities, in particular FOEN, in the establishment of standards in natural hazard management. Together with other federal agencies, WSL engages in the coordination of natural hazard warnings for the public (Steering Committee for Intervention in Natural Hazards, *LAINAT*).

5.5.4 Future research directions

In the future, WSL will further improve process understanding to address the unprecedented changes in the Alpine environment, with a particular focus on cascading and compound events. Scenario development will be key in successfully coping with risk management challenges. The focus on cascading and compound events will be supported by strengthening WSL's capacities in integrated field experiments and modeling expertise, including implementing the newest machine-learning-aided forecasting methods. The newly established CERC will make full use of the findings from these research activities, in close collaboration with cantonal and federal risk management stakeholders.

5.6 Thematic area: snow and ice

The cryosphere – snow, ice, permafrost and glaciers – is undergoing rapid changes worldwide as it responds sensitively to atmospheric changes. Snow and ice are of high relevance for Switzerland because of their critical role in the earth system but also because of their importance for tourism and hydropower production in this country. Winter tourism, for example, currently adds about CHF 7 billion to the gross domestic product of Switzerland, which corresponds to roughly 1%. Further, studying cryospheric processes and their links to hydrology is the basis for successful natural hazards prevention and warning (Section 5.5).

5.6.1 Research

A key question regarding the cryosphere is how shrinking snow and ice covers will affect the climate system, natural hazards, the availability of water resources, and tourism. To address the influence of snow, however, the micro-scale needs to be linked to the global scale, as snow microstructure affects radiative transfer, which in turn needs to be incorporated, in an adequately parameterized form, into climate and earth system models. A holistic modeling approach, with snow and ice as key components in the earth system, is thus needed to address the challenges associated with snow and ice in mountains and at the poles.

For micro-scale snow research, the cold laboratory in Davos is internationally recognized and facilitates year-round controlled experiments, including those with an upgraded micro-computed tomography (micro-CT) scanner. The expertise of WSL researchers on snow and ice has opened new opportunities for snow research in polar regions. On the *MOSAIc expedition* (Multidisciplinary drifting Observatory for the Study of Arctic Climate), WSL contributed the majority of instrumentation and methodology for the snow research part (Figure 5.6).



Figure 5.6: Research vessel “Polarstern” trapped in the Arctic sea ice during the MOSAIc expedition. Photo: S. Hendricks.

In the area of snow hydrology, WSL has led the integration of the results of small-scale field studies into *large-scale (entire mountain range) models* of snow deposition and melt. In addition, the introduction of *modern remote sensing tools* has enabled major advances in the mapping and monitoring of snow deposition, which enables improved runoff predictions and snow avalanche hazard assessments.

WSL also studies the effects of changes to mountain permafrost on, for example, *high-elevation infrastructure*. Since 1996, permafrost in the Swiss Alps has been monitored through the Permafrost Monitoring Network (*PERMOS*), which supplies essential data on the state of permafrost and improves the understanding of the complex interactions between the ground surface and underlying substrates, as well as the effect of *snow coverage and avalanche deposits on permafrost*.

WSL has substantially increased its research activities in *glaciology* over the past years, and it now covers glaciers in the changing climate and their impacts on *water resources* in High Mountain Asia, the Andes and the Alps. WSL's research in glaciology ranges from field monitoring and remote sensing to cutting-edge process understanding and model development. For example, in recent high-impact studies involving WSL scientists, the *volume of glacier ice on earth* and the *extent and stage of supraglacial debris* were determined and numerical models were developed to better *predict the response of glaciers to sustained climate warming*.

5.6.2 Knowledge transfer and application in practice

Building on its basic research on snow, permafrost and glaciers, WSL generates and applies knowledge in areas of great importance for Switzerland. These topics include snow and snow water resources, the development of *snow management procedures for ski resorts*, the impacts of glacier changes on water resources and *hydropower production*, and the impacts of changes to mountain permafrost on infrastructure, landscape evolution and natural hazards. The research program CCAMM integrates research on impacts due to changes in the mountain cryosphere.

Research sites of international relevance include the snow field test site on *Weissfluhjoch*, which hosts a unique snow data series extending over 80 years, and the Swiss alpine remote sensing test site in *Davos Laret*, both of which belong to the *Integrated Cryonet Cluster Davos* of the World Meteorological Organization (WMO). WSL has additionally built projects with the European Space Agency (ESA) in the area of microwave modeling, active and passive microwave measurements, and snow characterization.

WSL contributes to national monitoring of *snow*, glaciers and permafrost in the framework of the Global Climate Observing System (GCOS) Switzerland. It also maintains an *operational snow-hydrological service*, which includes continuous analysis of the spatial and temporal distribution of snow water resources in Switzerland, thereby facilitating improved hydrological forecasting and timely regulation of water resources.

WSL is also heavily involved in teaching at the university level in Switzerland and abroad. For example, WSL researchers teach all relevant courses in cryospheric sciences at ETH Zurich and EPFL. The *European Snow Science Winter School*, the only winter school worldwide to teach modern methods of snow characterization, was co-founded and is co-organized by SLF.

5.6.3 Outreach to society and politics

WSL's unique position with regard to alpine permafrost, snow and glacier monitoring is an asset in outreach activities. In particular, the *long-term data series of snow measurements* are used in *snow climatology* studies, which are attracting growing interest from society. Indeed, information on the fate of Alpine snow cover is presented frequently in public talks and panel discussions on climate change impacts in mountain regions. Further, snow load considerations in building design are based on the long-term snow data series, and *WSL researchers are thus consulted by engineers and architects concerning the design of infrastructure in extreme environments*. Finally, small-scale snow distribution data from an unmanned aerial system (UAS) is becoming increasingly relevant in the consulting services provided (e.g., to railway companies) on *snow drift measures to protect mountain railways*.

5.6.4 Future research directions



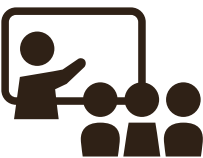
In the future, WSL will place an even stronger focus on the role of snow in the earth system and will particularly foster the link between microstructural research and regional and global modeling. Further, research efforts will be directed towards generating more accurate run-off predictions, deepening the understanding of the snowpack's response to extreme rain-on-snow events, and improving the modeling of water–permafrost interactions. Finally, with the increasing need for additional energy production, optimizing energy production in an integrated way in snow and ice environments is emerging as a key research topic at WSL. Specifically, *photovoltaic energy production* is highly efficient in high-mountain areas, due to the high reflectivity of snow, and WSL can contribute substantially to research on this topic with its vast expertise and know-how.

6 Performance and Productivity

In its five core thematic areas, WSL strives for excellent research at the national and international level. It aims to be well positioned in the dynamic and competitive international setting, while also maintaining its important bridging function between fundamental research and application in Switzerland.

WSL monitors its qualitative and quantitative performance and the impact of its publications and reports them to the ETH Board. Internally, qualitative and quantitative performance goals of the research units and groups are determined and evaluated in annual discussions (MbOs) between the Director and the heads of the research units. To assess its annual performance in the different core activities (research, knowledge transfer and application in practice, teaching and student supervision, outreach to society and politics), WSL uses a range of indicators that are measured annually, based on information provided by the researchers. Table 6.1 provides an overview of selected indicators for the year 2021. Times series between 2017 and 2021 are provided in Appendix I Facts and Figures. More qualitative output of the WSL research units is described in SAR Volume 2.

Table 6.1: Overview of selected indicators in WSL's different core activities in 2021. More details follow in the subsequent sub-sections.

Core activities	Indicators in 2021
Research	
	<ul style="list-style-type: none"> • 698 scientific publications in journals indexed in the Web of Science Core Collection (WoS CC), 82% of which are open access • 72 peer-reviewed scientific publications in journals not indexed in WoS CC • 440 contributions of WSL employees to the scientific community (e.g., conference contributions)
Knowledge transfer and application in practice	
	<ul style="list-style-type: none"> • 332 practice-oriented publications written by WSL employees • 30 collaboration contracts with the Swiss public sector and five with private partners (each > CHF 50,000) • 1 invention disclosure and 86 licenses (mainly for use of RAMMS software)
Teaching and student supervision	
	<ul style="list-style-type: none"> • 3247 hours taught at the two Swiss federal universities (ETH Zurich, EPFL), at cantonal universities, at Swiss universities of applied sciences, and at tertiary-level institutions abroad • Supervision of 160 PhD theses and 171 bachelor's & master's theses by WSL employees • Contributions to 13 winter/summer schools and workshops • 28 professors working at WSL and in various universities in Switzerland and abroad
Outreach to society and politics	
	<ul style="list-style-type: none"> • 380 practice-oriented contributions from WSL employees (e.g., excursions, workshops, courses for continuing education) • 2171 contributions in print/radio/TV, including 290 radio and TV reports about WSL research activities

Reference to ToRs:

I. Overarching questions

(2) Quality

(3) Productivity

6.1 Research

6.1.1 Scientific publications

In 2021, WSL scientists published nearly 700 peer-reviewed scientific articles in journals indexed in the Web of Science Core Collection (WoS CC). During that year alone, articles published (in any year) by WSL authors were cited 47,000 times in total. This large number of citations is an indication of the substantial impact of WSL research in the scientific community. WSL researchers also publish 60 to 120 peer-reviewed scientific publications annually in journals not indexed in WoS CC. These scientific publications include reference works (e.g., articles, books, reports) targeting an academic audience or an expert group outside academia.

A bibliometric analysis of WSL's scientific output and impact was recently conducted (*CWTS Bibliometric Report 2022*). It was based on the period 2009–2020 (including citations up to 2021) and included publications in journals and proceedings processed for the Web of Science. During this period, WSL produced a total of 4936 publications. About 13% of WSL's publication output is listed in the Web of Science subject category “ecology”, 12% in “forestry”, and 11% in “geosciences and multidisciplinary”. Figure 6.1 shows not only the increasing number of WSL publications over time, but also the high citation impact. When considering the WSL publication output in eight periods of four years each, it is clear that the number of scientific publications nearly doubled between 2009 and 2019. Particularly remarkable is the increase in impact, represented by the total number of citations (total citation score, TCS), which more than doubled over the decade. In addition, the average number of citations per paper (mean citation score, MCS) shows that WSL publications received 30% more citations per article in recent years (increase from 10.7 to 13.9).

WSL publications have a high citation impact compared with all other publications in the world in the same field and same year (“benchmarking”). This is illustrated by two field-normalized impact indicators: (1) the mean normalized citation score (MNCS) and (2) the proportion of publications in the top 10% most cited publications (PP top 10%). Overall, WSL's MNCS is 1.42, meaning that WSL publications have been cited 42% more

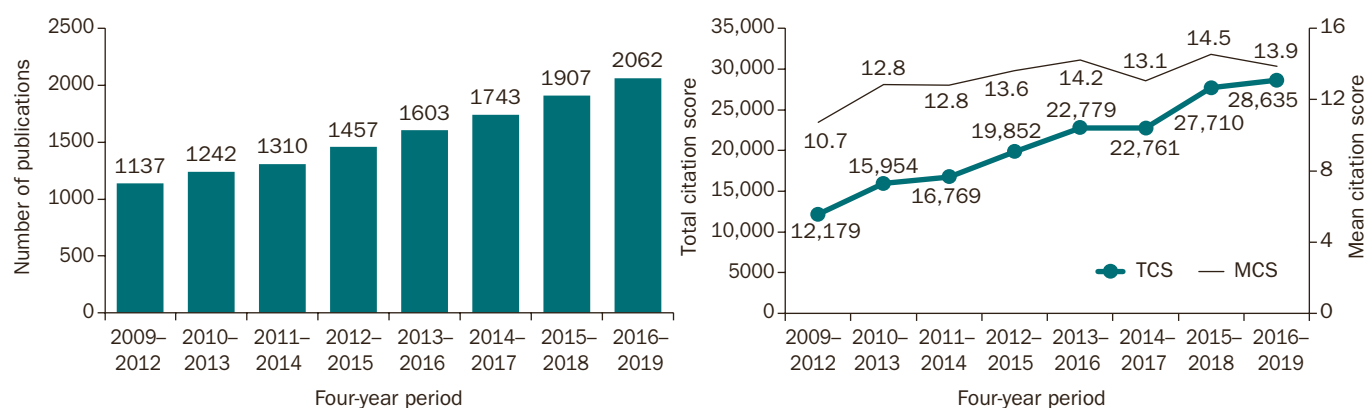


Figure 6.1: Left: Number of reviewed scientific publications during four-year periods. Right: Total citation score (TCS) and mean citation score (MCS) per article. The number of citations is counted for the publishing year plus the following three years, excluding self-citations. For instance, for a publication from 2017, citations are counted from 2017 through 2020. Source: Centre for Science and Technology Studies (CWTS), Leiden University, study for the ETH Domain, period 2009–2020, data from Web of Science.

than other publications in the same research area and in the same publication year (without self-citation). In some areas, WSL's MNCS is much higher, for example reaching 2.78 for multidisciplinary science. The indicator PP (top 10%) shows that 16% of WSL's publications are among the top 10% most cited publications in its broad research field. This value is higher for some specific areas such as microbiology (32%) and evolutionary biology (26%). These very high MNCS and PP scores speak to the excellent quality of WSL's research activities and the strong networking of its researchers.

6.1.2 Accessibility of scientific publications

Aware that its research is of great relevance to society, policy-makers, scientists and practitioners, WSL is increasingly publishing its research as open access (OA). The aim in the national strategy adopted by the Swiss higher education institutions is for all publicly funded publications to be freely accessible as of 2024. WSL strives to increase its OA publication, as demonstrated by the increasing share of OA from 2009–2020, from 49% to 70% (CWTS Bibliometric Report 2022). About 82% of the journal articles published in 2021 and indexed in WoS CC are OA, according to their registration in DORA, the WSL internal repository database. WSL is committed to achieving full OA publication wherever possible and in accordance with confidentiality.

6.1.3 Outreach to the research community

Besides through publications, WSL reaches the scientific community by presenting its research results at conferences and seminars. Between 2017 and 2021 (including the COVID-19 period), WSL researchers contributed, on average, 440 times per year to diverse scientific conferences, held in worldwide locations, by giving oral presentations (80%) or presenting posters (20%). The figures for 2020 and 2021 were 40% lower than in previous years due to the pandemic. Additionally, between 2017 and 2021, WSL staff organized or co-organized, on average, 132 scientific events per year in the role of session chair or member of the organizing/scientific committee for conferences. With its researchers' strong participation and contribution to scientific events throughout the world, WSL shares its findings widely and promotes collaboration.

6.2 Knowledge transfer and application in practice (including teaching/supervision)

WSL transfers science-based results and offers recommendations to governmental authorities and practitioners in Switzerland. WSL's many activities, such as practice-oriented publications, scientifically based services and tools, software, websites and apps, are instrumental in this knowledge-transfer process. Teaching also represents a form of knowledge transfer that is important for WSL.

6.2.1 Practice-oriented publications

Many of the results from WSL research are of great relevance to practitioners in Switzerland and abroad. A consistently large share of its publications therefore mainly addresses this target group. In general, these publications are not reviewed and are published in one or more (Swiss national) languages. They include magazine articles, books, reports and brochures, as well as journal articles published in professional journals with specific target audiences. The share of practice-oriented publications has remained at around one-third of WSL's total publication output over the last 5 years, corresponding to around 300 publications yearly.

In addition to many articles in professional journals, several books were published in 2021, such as “How to balance forestry and biodiversity conservation” (which provides a Europe-wide overview of current approaches to integrated forest management), “Sur les sentiers valaisans de la recherche” (also available in German; Figure 6.2), “Le selve castanili della Svizzera italiana”, and the second edition of “Insekten im Wald” (also available in English).

6.2.2 Scientifically based services and tools

Based on its reputation in research and application, as well as the unique combination of its five thematic areas of expertise in the Swiss environmental science landscape (Section 2.3), WSL carries out consultancy and advisory work for governmental agencies at all three levels (federal, cantonal and municipal) and for the private sector. This interaction results in a considerable number of research and scientific service contracts with public agencies each year, as well as some with the private sector. In 2021, for instance, 35 new contracts with a value > CHF 50,000 each were established with the public (30) and the private (5) sectors, with a total value of CHF 15.7 million. In addition, WSL researchers develop information portals, computer models and software tools, considering also the multilingualism needs of society or practitioners. Several examples of activities related to knowledge transfer and application were presented in Section 5. To give an overall impression of knowledge transfer at WSL, Table 6.2 shows a selection of current activities.

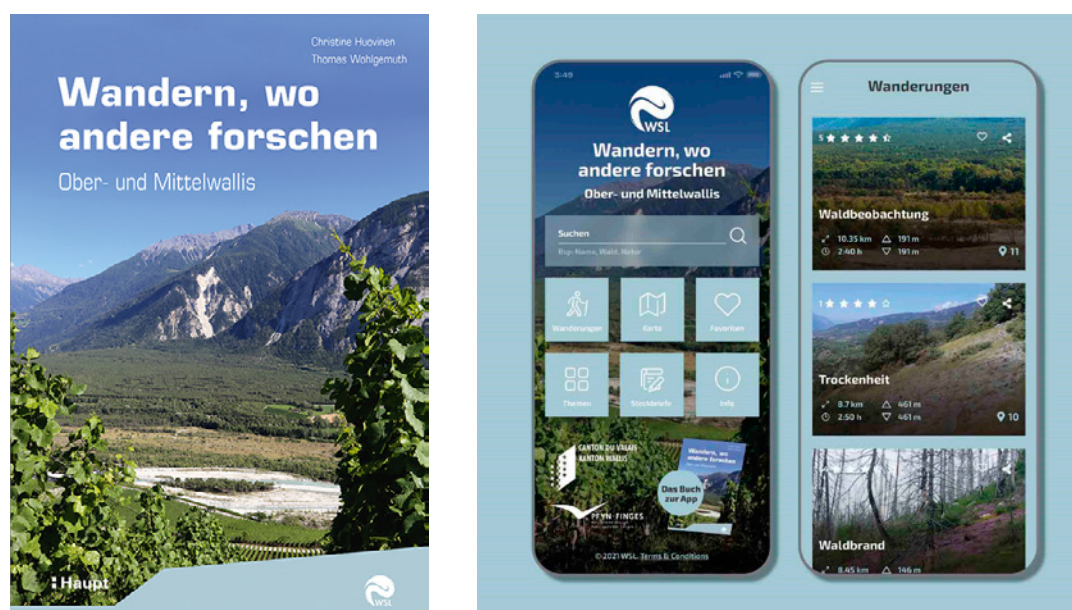


Figure 6.2: WSL's first hiking guide presents eight tours of the most important WSL research sites in the canton of Valais. The *smartphone app* helps with orientation and reveals information about research, fauna, flora and geology.

Table 6.2: Selected examples of knowledge transfer and application in practice in the different thematic areas of WSL.

Thematic area	Activities	Type of application
	<i>Diagnosis and advice online:</i> The diagnosis program Forest Protection Switzerland helps users to determine forest and tree damage (in German and French).	Expertise and advice
	<i>HeProMo:</i> This wood harvesting productivity model offers an easy and rapid assessment of the time required, productivity and cost of various wood harvesting operations.	Software, websites and app
	<i>Bark beetle forecast in Switzerland:</i> This website presents the modeled daily development of bark beetle populations in Switzerland on a 2 × 2 km grid, including the swarming flight of the beetles. In addition, forecasts of the population development until the end of the year can be called up under average weather conditions. This is a joint project of WSL and FOEN (in German and French).	Forecasts and warnings
	<i>Monitoring the effectiveness of habitat conservation in Switzerland WBS (FOEN and WSL joint project):</i> To protect precious habitats and their biodiversity, Switzerland designated about 7000 sites of national importance. These sites are legally protected and include mires (fens and raised bogs), dry grasslands, flood plain habitats, and amphibian breeding sites.	Data, monitoring and inventories
	<i>Totholz und alte Bäume</i> (in collaboration with the Bern University of Applied Science and FOEN): This internet platform aims to promote knowledge about old trees and deadwood, with the goal to increase the proportion of old and dead wood in the Swiss forest.	Software, websites and app
	<i>Biodiversity-damaging subsidies in Switzerland:</i> An overview of Swiss subsidies with biodiversity-damaging effects can be explored in greater depth by topic, filter or text search in a web application (in German).	Software, websites and app
	<i>Datacenter Nature and Landscape (DNL):</i> The aim of this project is to integrate existing national biotope inventories (e.g., bogs, flood plains, meadows) into a database and connect them to further FOEN data sources. The lineage of the data, with all scientific and political processes, is also documented.	Data, monitoring and inventories
	<i>Relationship of the Swiss population to the forest</i> (report in German): Based on repeated surveys in the framework of the sociocultural forest monitoring WaMos, this report targets federal and cantonal authorities and presents the relationship of the population to the Swiss forest.	Reports
	<i>GoApply:</i> This interactive map for climate adaptation governance helps to identify and visualize the most relevant climate change adaptation activities in alpine space.	Software, websites and app
	<i>FireNiche:</i> A statistical method for detecting forest fire risk. The “forest fire niche” is defined by the particular weather constellation that prevailed on the fire days. The models were developed on the basis of the forest fires that have occurred in the last 20 years. The cantonal observatory “Osservatorio ambientale della Svizzera Italiana OASI” has implemented the FireNiche method in the IT system of the cantonal administration.	Forecasts and warning
	<i>Expert opinions on avalanche protection:</i> SLF disseminates its technical know-how on avalanches in the form of expert opinions and advice for public bodies, such as civil engineering offices and local authorities, as well as private organizations, including engineering companies and railway and cableway operators, both in Switzerland and abroad. These expert opinions are also provided for other natural hazards, such as <i>debris flows in mountain torrents</i> .	Expertise and advice
	<i>White Risk portal</i> and app: This tool helps to ensure that winter mountain tours are as safe as possible. It can be used at the planning stage, while in the field, and for education and training purposes.	Software, websites and app
	<i>SnowMicroPen ®:</i> This tool is a variant of a cone penetrometer for measuring bonding forces between snow grains at a high spatial resolution. It is used for various applications, such as snow profiling (avalanche forecasting, snow stratigraphy, ground truthing for remote sensing), ski track characterization (ski racing), and snow runway characterization (stability testing).	Instrument
	<i>Operational snow-hydrological service (OSHD):</i> By conducting ongoing analyses of snow water resources, OSHD contributes to hydrological forecasting in Switzerland. The analyses are based on a modeling framework that combines data stemming from snow measurements, several snowmelt models, and data assimilation techniques.	Forecasts and warning
	<i>Building on permafrost:</i> WSL tests new building methods on mountain permafrost and draws up practice-oriented recommendations to ensure the technical safety of mountain infrastructure.	Expertise and advice

6.2.3 Licenses, patents and spin-offs

Although WSL mainly works with the public sector, it also develops tools, such as software and technologies, that can be transferred to the private sector. In many cases, the products are used to manage public goods, such as protection forests against natural hazards. Therefore, tools developed at WSL usually remain the property of the institute, and the intellectual property rights of developed technologies are not transferred to the private sector. Indeed, the tools are continuously improved by integrating new results from the research conducted at WSL. The Rapid Mass Movement Simulation (RAMMS) software is a showcase example. It is the most widely used natural hazard modeling system for evaluating and facilitating protective measures. This instrument is at the disposal of practitioners and researchers alike. More than 80 licenses are handled directly by WSL every year for new clients all over the world (see Appendix I Facts and Figures). In 2020, WSL also reported one patent and created its first spin-off, TerraRad Tech AG. With its environmental radiometers and remote sensing technologies, this start-up enables unique soil moisture mapping and makes automation of agricultural irrigation systems possible on a large scale.

6.2.4 Teaching, education and student supervision

The teaching and supervision of students is another valuable channel WSL uses to pass on its research results in the five core thematic areas. In addition, WSL scientists make a valuable contribution to practical education at diverse institutions of higher education. Direct contact with bachelor's, master's and PhD students is of great importance to WSL, as it offers the opportunity to attract and encourage students with excellent qualifications to complete their degree theses at WSL. The institute thus contributes to the important task of Swiss authorities of preparing the next generation of specialists for the Swiss market, in both the private and public sector, and fostering new scientists in applied research.

WSL is engaged in teaching at the bachelor's, master's and PhD levels. Its teaching activities range from courses at ETH Zurich and EPFL, diverse Swiss universities, universities of applied sciences, and other institutions of higher education in Switzerland and abroad, to Massive Open Online Courses (MOOCs) and continuing education sessions for practitioners. More than 100 WSL staff (about one-third of the scientific staff) teach a total of more than 150 different courses every year. The teaching portfolio expanded in 2021, with more than ten new courses in all five WSL thematic areas. The quality of teaching is usually ensured and monitored by the universities themselves. For WSL, an additional indicator of the high quality of its teaching activity is the fact that teaching assignments for the same courses are continued over the years and new ones are developed.

In 2021, WSL staff taught 3247 hours at universities and other institutions of higher education (Figure 6.3), a number similar to that in previous years. About two-thirds of these teaching hours (2174) took place within the ETH Domain (ETH Zurich and EPFL), 671 were taught at other Swiss universities, and 232 at universities of applied sciences. The 170 remaining hours were taught at institutions of higher education abroad. Additionally, WSL researchers supervise PhD and master's students. In 2021, they supervised 171 bachelor's and master's theses and 160 PhD theses. Of the PhD students supervised by WSL staff, 62% were matriculated at ETH Zurich or EPFL in that year.

At the end of 2021, WSL had 28 employees with a professor title from universities in Switzerland or abroad. This encompasses four ordinary professors, four assistant professors, two associate professors and eighteen honorary professors. Six WSL researchers held the academic title of Privatdozent (PD) with a *venia legendi* at the ETH Zurich and at the

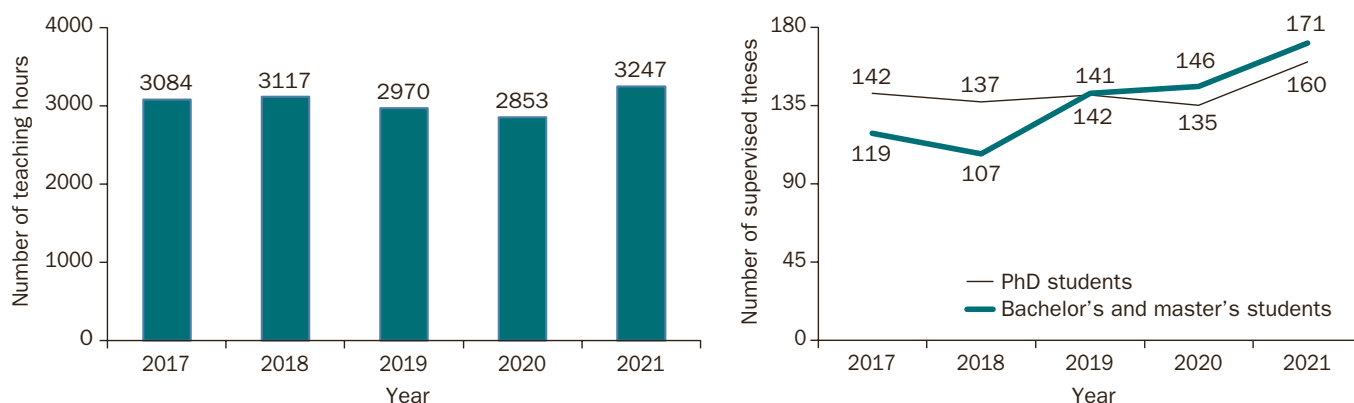


Figure 6.3: Left: WSL teaching load in hours; right: number of student theses supervised.

Universities of Bern or St. Gallen. The professorships held by WSL researchers guarantee that exchange with students is formalized and teaching interests are coordinated between ETH Zurich, EPFL and WSL.

Finally, field weeks and summer and winter schools are key components of WSL's teaching activities. Examples include: the *European Dendroecological Fieldweek*; *FORMON – Long-term Forest Monitoring* (Figure 6.4); the *International Course on Wood Anatomy and Tree-Ring Ecology*; *FORBIODIV – Biodiversity*, a key element for temperate forest ecosystems; the *International Summer School for Land System Science*; the *Swiss Climate Summer School*; and the *European Snow Science Winter School*. In the last five years (including the COVID-19 period), WSL staff held more than 1000 hours of teaching in summer and winter schools.



Figure 6.4: The summer school FORMON – Forest Monitoring to assess Forest Functioning under Air Pollution and Climate Change – held in 2021 provided an in-depth understanding of the concepts, approaches, and available data infrastructure of forest long-term monitoring. Photo: M. Kaennel Dobbertin, WSL.

6.3 Outreach to society and politics

With its outreach activities, WSL aims to reach a large audience or groups of mixed stakeholders to share knowledge about its basic research field with the general public, thereby increasing its visibility in society. Outreach activities take several forms, such as workshops, public talks, and events like the annual Forum für Wissen (knowledge forum). In all these activities, attendees from other scientific institutions, public administration and practice participate and interact with WSL scientists. In 2021, WSL made 380 practice-oriented contributions in the form of excursions, workshops and courses for continuing education. Several examples of important WSL outreach activities are described in Section 5.

WSL frequently communicates results and ongoing research throughout many channels, for instance, articles in newspapers and magazines, books, and various platforms and blogs (Section 4.4). In addition, the biannual institutional magazine DIAGONAL provides information about WSL's research and its findings. The most important national and international newspapers, as well as radio and TV news broadcasts in Switzerland and abroad, repeatedly and prominently feature WSL research, with a total of around 2000 reports per year. Taking into account its small size, WSL is the most present in the media of all the institutions of the ETH Domain: with about 2.5% of the budget of the ETH Domain, it provides about 5% of the total media presence of all the ETH Domain institutions.

7 Collaborations

Reference to ToRs:

II. Specific questions

Strategic focus (e)

Stakeholder involvement
and role in society (i)

Collaboration across organizational and cultural boundaries is essential in scientific research, as it extends the possibilities for gaining new knowledge and leads to a better understanding of the needs of the stakeholders and users of research outcomes. WSL scientists collaborate with a wide variety of partners across its research units, within the ETH Domain, and at the cantonal, national and international levels. These partnerships differ in terms of the purpose pursued, form and geographical spread. They all contribute to optimally addressing WSL's thematic areas, for example by bringing in complementary competences, building a bridge to important stakeholders, or disseminating WSL's expertise and services to scientists at other academic institutions. Certain partnerships are also intended to help advance environmental research in emerging or developing countries. While research collaborations are mainly carried out in an international setting, WSL's implementation and outreach activities primarily aim to serve Swiss society and are thus done mainly through national collaborations.

WSL actively supports a range of tools to promote collaboration at different levels (Table 7.1). In addition to these tools, WSL scientists benefit from a large range of funding schemes supporting collaborative projects in particular, funded by other bodies such as the European Research Commission (Horizon Europe), the Swiss National Science Foundation (SNSF), or the ETH Board for cooperation within the ETH Domain.

7.1 Collaboration within WSL

In addition to collaborations taking place in the framework of WSL programs and internal innovative projects supported by the Directorate (Section 3), many internal collaborations happen between different research units without any special program or encouragement. As an example, 15 researchers from 5 research units, all addressing aspects of forest regeneration, have intensified their collaboration in research and outreach by holding regular joint meetings and organizing conferences. Events organized bottom-up, such as a remote sensing lecture series, biodiversity seminars and statistics courses in R, lay the groundwork for these collaborations.

To promote certain strategically desired collaborations, the Directorate can initiate programs or design calls for internal projects accordingly (Section 3).

7.2 Collaboration within the ETH Domain

The Swiss Federal Council defines the strategic objectives and the four-year strategy for the ETH Domain (Section 2.5). To fulfill these goals, collaboration between all six institutions of the Domain is indispensable. Thus, the ETH Board not only encourages but also promotes such collaboration, for example with calls for topic-specific Joint Initiatives, which are co-funded by the ETH Board and the institutions. WSL researchers actively participated in two calls in 2022: "Engagement and Dialogue with Society" and "Energy, Climate and Sustainable Environment". WSL contributes to eight of the ten proposals selected for funding within the ETH Domain. Despite the research institute's relatively small size, WSL scientists submitted 13 full proposals with their partners (out of 18 submissions total). WSL researchers also participated in the Domain-wide calls about Open Research Data (ORD).

Table 7.1: Overview of the main tools supported by WSL to promote collaboration within the research institute and the ETH Domain, as well as at the cantonal, national and international levels.

Field of activities	Within WSL	Within ETH Domain	Cantonal and national level	International level
Research	Internal call for innovative research projects; WSL programs	Joint Initiatives; ENRICH; joint and adjunct professorships	Cooperation agreements with cantons (e.g., Valais, Grisons), universities and universities of applied sciences	WSL fellowships; memoranda of understanding with universities from all over the world
Implementation, knowledge and technology transfer (KTT), and outreach	Internal call for innovative implementation projects; WSL centers	Public Affairs group; Working group of heads of communication	Cooperation projects and agreements with public sector (e.g., cantonal and federal offices); internal call for innovative implementation projects; stakeholder events (e.g., <i>Forum für Wissen</i> , <i>SwissForestLab Dialog</i>); WSL centers (e.g., <i>CERC</i>); WSL extension service <i>Interface Research-Practice</i> for western Switzerland; extra-parliamentary commissions	Web platforms (e.g., <i>Waldwissen</i>); patents and licenses
Infrastructure	Major investments; WSL programs	ENRICH; <i>Open Research Data (ORD)</i> ; laboratories (e.g., <i>Genetic Diversity Centre (GDC)</i> and <i>Laboratory of Ion Beam Physics (LID)</i> at ETH Zurich	WSL programs; <i>laboratories</i> (e.g., WSL plant protection lab)	International networks of research infrastructures (e.g., <i>eLTER</i> , <i>ICOS</i>)
Support and technical services	Techniker-Netzwerk (technician network);	Joint services (e.g., <i>Lib4RI</i> library, technical services for construction at Empa “Bau3FI”); ENRICH; working groups (e.g., heads of IT / Finances / HR / KTT)		
Networks and other	Frauen Netzwerk (WSL network for women); <i>women's peer mentoring group</i> ; PhD club	<i>Fix the Leaky Pipeline</i> ; feM-LEAD (women's mentoring program)	CONNECT in academia and industry; P7 – Sexual Harassment Awareness Day	

ENRICH is a complementary bottom-up initiative of the four federal research institutes (PSI, Empa, Eawag and WSL) within the ETH Domain, intended to intensify collaboration in science and support (Section 2.5). Three projects are currently planned: (1) to establish a joint organization for continuing education (Academy4Four); (2) to develop sensor technologies and applications; and (iii) to advance NetZero Research (research with net zero or negative carbon emissions) and implement it on campuses.

For collaborations with the federal universities ETH Zurich and EPFL, WSL's two full professorships, seven adjunct professorships, and three joint professorships with these two universities are of great value. In October and November 2022, two additional joint professorships with ETH Zurich will start at SLF in Davos, as part of CERC. These formal collaborations complement numerous joint activities, such as lectures, joint supervision of students, research projects and networks (e.g., WSL program SwissForestLab), which often also include partners outside the ETH Domain.

7.3 National collaboration

Many of WSL's activities include applied science and target practitioners in Switzerland from the federal, cantonal and community levels, as well as practitioners in the private sector. WSL has built a relationship of trust with its stakeholders over the years. Due to its scientific expertise, WSL is a sought-after partner for public institutions and signs several dozen contracts with the public sector every year, including FOEN and various Cantons (Section 6.2.2). The establishment of CERC in Davos is a recent example of close cooperation with Canton Grisons, ETH Zurich and the municipality of Davos. WSL also has cooperation agreements with Canton Valais, as WSL operates several large infrastructures in that canton (e.g., avalanche test site at Vallée de la Sionne, irrigation experiment in Pfynwald; Section 4.3). WSL also operates an *extension service* to facilitate the interface between research and practice for the French-speaking region of Switzerland.

WSL is a co-founder of the *Swiss Polar Institute* (SPI), an interdisciplinary center based at EPFL that is devoted to studying the earth's poles and other environments of extreme cold, including high alpine regions. SPI is a consortium of Swiss research institutions – EPFL, WSL, ETH Zurich and the Universities of Bern and Lausanne – and was co-founded by Editions Paulsen, a private publishing company.

Finally, WSL is part of many important national initiatives and expert committees. Examples include: (1) participation in the *Steering Committee on Intervention in Natural Hazards* (LAINAT); (2) membership in the *National Centre for Climate Services* (NCCS); (3) participation and membership in several national extra-parliamentary committees on noise control, spatial planning, and natural hazards (*National Platform for Natural Hazards* PLANAT); (4) various roles in the *Swiss Academy of Sciences* (SCNAT); and (5) participation in the network of mountain forestry professionals GWG (Gebirgswaldpflegegruppe). In addition, WSL employees are actively involved in numerous professional societies and networks (e.g., Swiss Forestry Society, Swiss Soil Society).

WSL naturally also cooperates in many research projects and teaching activities with all Swiss universities and with many universities of applied sciences.

7.4 International collaboration

WSL researchers are engaged in a worldwide research network, with close collaborations across all five continents. Research projects, international conferences, organization of international summer and winter schools, and publications are all ways in which WSL collaborates internationally (see Section 6 and SAR Volume 2 for further examples). For instance, WSL is currently a partner in 7 ongoing European collaborative projects, each involving between 9 and 35 additional partners, and 5 new collaborative projects will start in 2022 or early 2023 (see below). At the institutional level, WSL actively promotes international partnerships and, when useful, considers formal cooperation, for example through memoranda of understanding (MoUs).

The vast international cooperation is well reflected in WSL's publication record. Most of WSL's scientific publications (80%) are co-authored with scientists from outside Switzerland, demonstrating the research institute's intensive collaboration with the international scientific community. The percentage of publications involving international collaboration has increased over time, as shown by the recent bibliometric *CWTS study*, suggesting an increase in corresponding collaborations. Measured in terms of co-authorships, WSL collaborates most often with German institutions, followed by those from the United States, France, the United Kingdom, Italy, Spain and the Netherlands, but it truly collaborates with scientists from countries all over the world (Figure 7.1).

To further strengthen collaborations with the best scientists from all over the world, WSL established a visiting fellow program in 2014. These fellowships are advertised internationally every year. The WSL Directorate selects scientists who wish to collaborate closely with WSL researchers and supports them financially during their stay at WSL. Since the program's initiation, 45 experienced senior researchers and professors have spent several months at one of WSL's sites in order to pursue projects with WSL researchers.

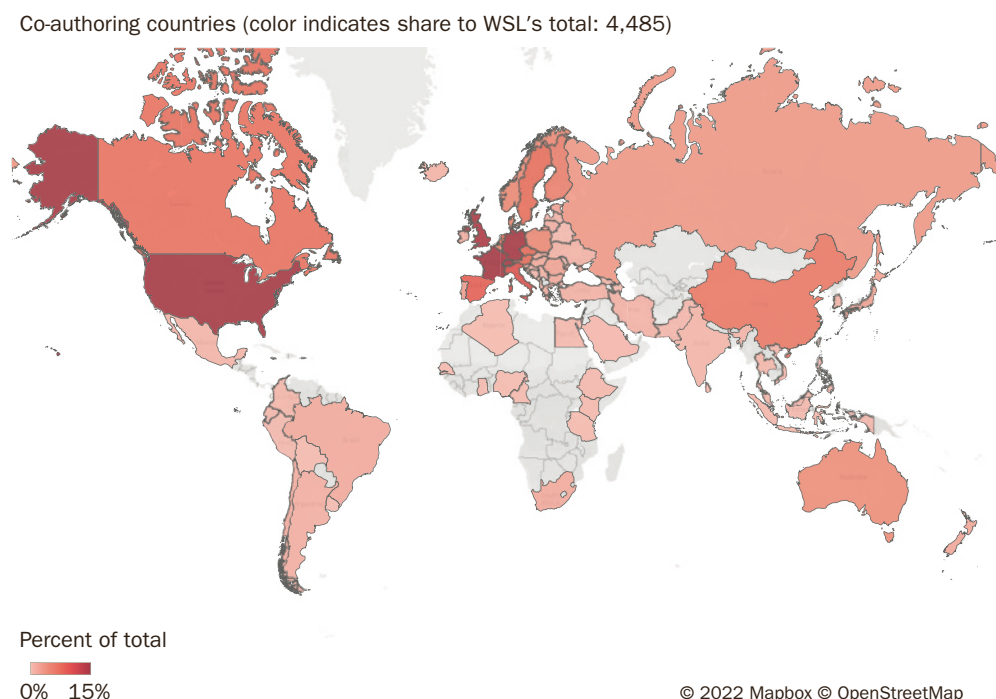


Figure 7.1: Countries where co-authors on WSL publications are based. Color intensity represents the percentage of WSL's total number of publications with external collaborators in 2009–2020 (4485 publications done in collaboration). Source: Figure 13 in CWTS Bibliometric Report 2022.

Projects funded by the European Commission are traditionally an excellent opportunity for international cooperation. Since summer 2021, Switzerland has been considered a non-associated third country in Horizon Europe and related programs and initiatives. However, Switzerland can participate as an associated partner in most Horizon Europe calls for collaborative projects, and funding for successful proposals is secured by the Swiss State Secretariat for Education, Research and Innovation (SERI). Thanks to this mechanism, five Horizon projects including WSL as associated partner were funded in 2022, ensuring further international collaboration in Europe. However, it is not possible for Swiss organizations to lead/coordinate collaborative Horizon projects. This might negatively affect WSL's attractiveness to foreign researchers and its reputation as a key player in terrestrial environmental research, especially over the longer term.

WSL scientists have also been successful in acquiring collaborative grants funded by SNSF through various funding schemes intended to promote international collaboration (e.g., Weave/Leading House, bilateral programs of the Swiss Confederation, European Cooperation in Science and Technology (COST) Actions, International Co-Investigator Scheme, scientific exchanges). Currently, about 20 SNSF projects are running at WSL. These funding instruments will be further developed in the future, especially due to the non-association of Switzerland with Horizon Europe, and will thus be an excellent opportunity for WSL scientists.

WSL scientists are strongly involved in international networks and professional associations, which provide an excellent framework for collaborative projects. A few examples are the *International Union of Forest Research Organizations* (IUFRO), the *European Avalanche Warning Services* (EAWS; currently co-chaired by WSL), the *International Glaciological Society* (IGS), and the *International Union for Conservation of Nature* (IUCN). When it is of particular strategic importance for WSL, individual researchers are supported in actively engaging in international collaborations (e.g., Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES], Intergovernmental Panel on Climate Change [IPCC], World Meteorological Organization [WMO]); societies (e.g., European Space Agency [ESA], European Geosciences Union [EGU], International Association for Landscape Ecology [IALE]); and research networks (e.g., European National Forest Inventory Network [ENFIN], European research group EVOLution of TREEs as drivers of terrestrial biodiversity [EVOLTREE], Global Land Project [GLP], Global Climate Observing System [GCOS], International Association of Cryospheric Sciences [IACS], Nancy-Freiburg-Zurich Forest Research Network [NFZforest.net], International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests [ICP Forests]).

8 Future Opportunities

WSL's research is closely related to major global challenges, such as climate change, biodiversity loss, land-use change, and resource and energy crises. Based on these challenges, WSL develops science-based options relevant for Switzerland at a range of scales. With its mandate (Section 2), thematic portfolio (Section 5), and organizational structure (research units, programs, initiatives and centers; Section 3), WSL is well prepared to provide robust scientific knowledge to its stakeholders and, at the same time, to respond to new challenges in an agile manner. Developing and applying new, innovative environmental science approaches and fostering collaborations across disciplines will be crucial for addressing upcoming societal challenges related to the current global crises.

The WSL Directorate has identified several opportunities for the future thematic development of the research institute. It sees possibilities to continue research and outreach in these themes, but with an even stronger focus on crosscutting activities, taking into account the context of increasing resource scarcity, competition for ecosystem service provision, and land-use conflicts. Five topics were identified that offer exciting new opportunities for WSL's research and where WSL has the potential to contribute substantially in the near- to mid-term, i.e., over the next three to six years, for the benefit of Switzerland. All of the topics discussed below are well-embedded in WSL's five core thematic areas, forest, biodiversity, landscape, natural hazards, and snow and ice (Section 5), and thus largely build on existing competences and infrastructure.

8.1 Strengthening the natural resistance and resilience of ecosystems

Warmer and drier conditions are increasingly challenging for keystone species in most ecosystems in Switzerland and in Europe overall. Recent drought years have confirmed or even exceeded earlier predictions of climate-driven growth limitations. In the face of the manifold effects of climate change, it is critical to closely monitor the status of forest ecosystems, through networks such as NFI, LWF and TreeNet, and the effectiveness of habitat conservation across wide spatio-temporal scales. This monitoring work is the foundation for the reliable data required to build system knowledge and to provide adequate decision support for strengthening the resistance and resilience of different types of ecosystems. In this regard, WSL combines cutting-edge technologies, such as real-time water fluxes and fine-scale growth changes, with representatively measured long-term parameters to quantify changes from days to decades. Managed forests and protected forest reserves serve WSL as natural labs to study long-term changes in forest ecosystems. WSL sees a tremendous opportunity to apply these technologies and methods beyond forest ecosystems, for instance to urban ecosystems. Three research foci are described below to demonstrate WSL's leading role in forest sciences now and in the future, and to illustrate where new opportunities could unfold regarding urban ecosystems.

Focus 1: Climate-fit tree species

Which tree species will resist future climate conditions? In interdisciplinary climate manipulation experiments simulating hotter drought conditions, species and provenances are exposed to environmental conditions and various treatments to disentangle the role of atmospheric and soil drivers in forest growth and overall functioning. WSL's flagships for related future research activities are internationally renowned long-term experiments in forests, such as the Pfynwald irrigation site and the Lötschental tree-growth monitoring transect. In addition, an experimental plantation network has recently been established at 60 localities across Switzerland, complemented by three sites with so-called polytunnel facilities, i.e.,

Reference to ToRs:

I. Overarching questions

- (1) Relevance
- (4) Dynamics
- (5) Opportunities

II. Specific questions

Institutional level (a) (b)

Strategic focus (d)

Long-term research and monitoring (f) (g)

Stakeholder involvement and role in society (i)

mobile polytunnel greenhouses where the future climatic conditions for a specific site can be simulated (Figure 8.1). At the same time, such types of experiments can provide insight into the changing resilience of urban trees and urban green spaces under climate change.



Figure 8.1: Mobile polytunnel greenhouses used to simulate warmer and drier conditions on the Swiss Plateau. The corresponding control plot for the experiment is shown in the foreground. Photo: B. Moser, WSL.

Focus 2: Climate-smart management of ecosystems

Climate-smart management options will need to be developed in response to the growing demand for a wide range of ecosystem services, driven by the energy and biodiversity crises and by climate-change-forced extreme events such as droughts and storms. Complex planning and management must progressively integrate new research findings and wrap them into decision support tools, for example for forest managers, considering site conditions over the long term. For example, historical forest management systems, such as coppice and coppice-with-standards, need to be evaluated regarding their productivity, nature conservation value, and resilience under climate change.

Focus 3: Functional biodiversity and interactions with non-native species

Activities related to the functions of biodiversity in various ecosystems are expanding at WSL in the face of climate warming, shrinking habitats and continued urbanization. Interactions between native biota and non-native species pose an increasing challenge to the conservation of the native flora and fauna. Advanced research on this topic addresses species traits, ecosystem services, and impacts of non-native species on natural habitats and native biota. WSL plans to intensify its research on the potential of urban green spaces to support biodiversity and on the capability of intraspecific diversity to withstand climate change. The assessment of biological diversity using newly developed artificial intelligence (AI) tools will be expanded as well, e.g., to make better use of the rapidly growing citizen science datasets and environmental datasets in Switzerland and elsewhere. Biodiversity assessments at WSL will be expanded to include soil biodiversity using environmental DNA (eDNA) metabarcoding.

8.2 Urban ecology and livable cities

More and more people are living in cities and urban areas, including in Switzerland. The human need for an attractive and livable environment that is able to adapt with climate change has to be combined with the needs of nature for space for biodiversity and ecosystem processes in the limited urban area. Concepts are required that consider various ecosystem services and human needs and how to bring them together through multifunctional approaches in urban open spaces.

WSL's approach to urban ecology is broad, involving the development of options to achieve a balance between humans and nature in the urban environment. In this context, it is also important to consider cities in relation to their surroundings and to determine where the respective system boundaries lie. WSL researchers have been addressing urban ecology topics for years. Research foci have included urban biodiversity, planning for green infrastructure in urban regions, urban–rural connections, and ecological and societal values of community gardens. WSL has already conducted two research programs about the progress of urban sprawl and its consequences for biodiversity and human well-being. Moreover, several projects in the framework of the ongoing Blue-Green Biodiversity Research Initiative 2021–2024 focus on urban environments. Research on urban green infrastructure and urban-regreening will be advanced by evaluating effects of vegetation transpiration and assessing habitat richness and biodiversity interrelations in the framework of a newly established “urban living lab”.

There is potential to further strengthen research activities in this field at WSL and to support Switzerland in making its cities together with their surroundings more sustainable. In future activities, WSL will benefit from its broad expertise in ecology, plant physiology, biodiversity and forest research. Many methods developed for and insights gained from research on natural habitats are expected to be transferable to the study of urban areas and their habitats, e.g., regarding urban forests, urban trees, parks and blue-green infrastructure.

Addressing urban ecology in a comprehensive, coordinated effort will allow WSL to develop its contribution to this interface of the ecological and human dimensions. WSL's research culture in landscape science that focuses on this interface is unique and is supported by the established tradition of interdisciplinary work within the institute. Another emerging opportunity is the combination of spatial and systemic approaches, adapting integrative landscape analysis to address questions of urban ecology, including urban–rural relations, land consumption, and perception of urban sprawl. Further possibilities are the development of new planning and management solutions in cities, e.g., the development of blue-green infrastructures, for a range of purposes, such as climate adaptation, biodiversity preservation, water management, recreation and health. Finally, a stronger focus on urban ecology also offers a unique opportunity for WSL to develop new methods bridging research and implementation, e.g., to understand the desired qualities for livable cities based on urban living labs.

8.3 Environment and human health

In line with the World Health Organization's (WHO) definition of human health as a “state of comprehensive physical, mental and social well-being and not merely the absence of disease or infirmity”, the field of prevention is increasingly including interfaces with environmental sciences. The One Health approach, i.e., the call for collaborative efforts to attain optimal health for people, animals and the environment, has been attracting in-

creasing attention. A growing number of people are living in densely populated urban areas and leading a sedentary life with increasingly stressful working conditions (e.g., working from home). Considering this situation and the exposure to environmental stressors such as air and noise pollution and heat, greater attention should be paid to prevention, and here especially to the role the environment plays in human health and well-being.

WSL has well-recognized expertise in the effects of natural environments on human recreation, well-being and health; attitudes towards landscape change; the human–nature relationship; and the emergence of environmental attitudes, i.e., environmental psychology and environmental design. Besides classical measurement methods like surveys and field or lab experiments, innovative approaches have been applied to detect mechanisms of psychological restoration and stress reduction. Ongoing activities at WSL on the interactions between the environment and human health are related to, for instance, the restorative potential of green spaces in noise-polluted environments and ways to promote biodiversity in urban neighborhoods while also benefitting human health. Especially in the area of prevention and spatial planning, close collaborations exist with various public stakeholders, such as municipalities and their service departments (e.g., Grün Stadt Zürich), cantonal authorities (e.g., Canton Bern), and federal authorities (e.g., Federal Office of Public Health [FOPH] and FOEN). These collaborations should be expanded.

WSL sees an opportunity to leverage its interdisciplinary approaches to develop more in-depth knowledge on the interaction between human health and well-being and between the natural and built environment, with a focus on prevention. One of WSL's main aims regarding this topic is to develop new strategies for improved environmental and urban planning to provide healthy living environments and foster individual and public health. With the combination of skills and experience of WSL scientists in social and environmental science and their specific experience in human and plant preventive health projects, WSL is well equipped to contribute to Switzerland's well-being as a whole by strengthening its emphasis on the topic of environment and human health. Work on this topic will also promote multiple synergies with other institutions within the ETH Domain, as Human Health is one of the five Strategic Areas in the Strategic Plan 2025–2028 of the ETH Domain.

8.4 Ecological transition in complex systems

The decline in biodiversity and the deterioration of resources and ecosystem services are challenges caused by direct drivers, such as land-use change, exploitation of resources, climate change and pollution. The drivers themselves are underpinned by an array of societal causes, which can be demographic, sociocultural, economic, or related to institutions and governance (indirect drivers; Figure 8.2). Changes are often gradual but may still have major and often irreversible consequences if a critical threshold is reached. Addressing these challenges requires a deeper understanding of their root causes and processes, but above all systemic and integrated approaches to arrive at possible solutions. This is where transition science comes in, a comparably new research field focused on the interplay between humans and natural systems. A key aim in this field is the identification of leverage points for change and adaptation in complex systems.

WSL will foster its inter- and transdisciplinary research on ecological transition, including environmental processes of change, tipping points and thresholds in complex systems to support decision-making. This includes a better understanding of the drivers of ecological changes and their dynamics (e.g., by using findings from WSL's various monitoring activities and by modeling and scenario building), as well as a closer integration of societal, economic and governance aspects when developing possible solutions. Among other topics,

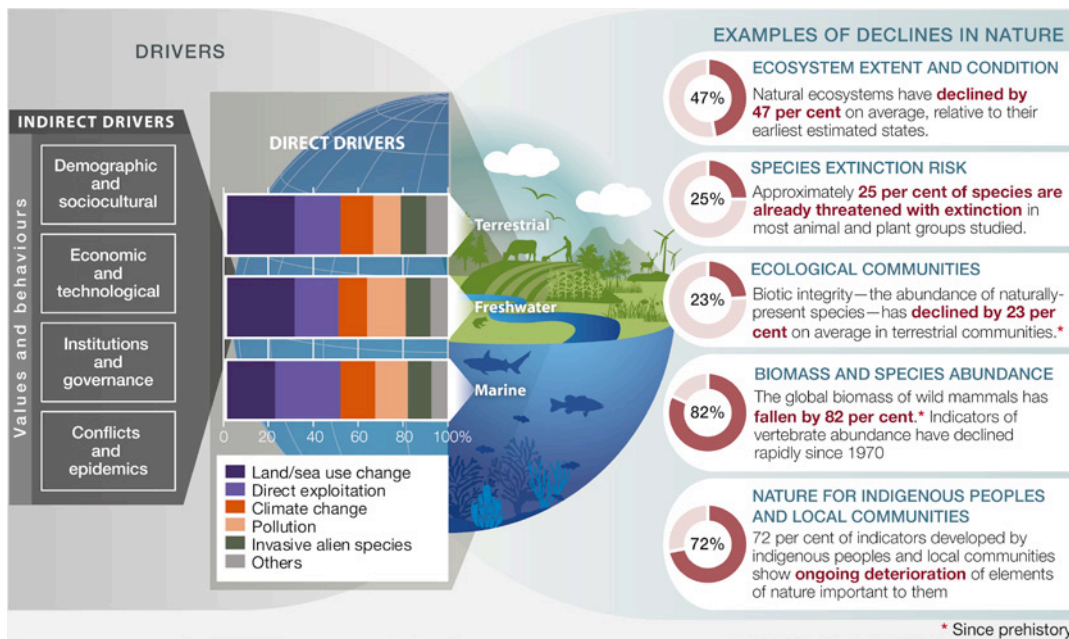


Figure 8.2: Examples of global declines in nature, emphasizing declines in biodiversity, caused by direct and indirect drivers of change. Image: IPBES Global Assessment 2019.

WSL will focus on: integrated approaches to cope with the decline in biodiversity and ecosystem services in the face of climate change; impacts of renewable energy systems on ecosystems and landscapes, and human perceptions of these systems; approaches to reduce land consumption and urban sprawl, and the implementation of these approaches in planning systems; and the prevention of natural hazards and mitigation of their impact on humans and natural systems.

8.5 Strengthening the interface between science, policy and society

The interface between science, policy and society is of utmost importance for WSL, as the institute strives to contribute high-impact research on societally relevant topics. Making knowledge and research findings available first-hand to politicians, authorities, practitioners and the public is a long-standing tradition at WSL, as demonstrated by the numerous articles in professional journals and newspapers, radio and television features, and university courses and training sessions for practitioners offered by the institute. WSL has identified two activities to strengthen the interface between science, policy and society, namely the pursuit of co-design in research and the targeted promotion of personal communication between experts at WSL and members of politics and society.

Exchanges at the interface between science, policy and society generally work well if they take place in dialogue as equals. WSL sees an opportunity to systematically involve stakeholders in co-design processes to define major research themes and specific research questions. Proven means for such transdisciplinary approaches include joint workshops in which the needs and problem-solving approaches of stakeholders are discussed. WSL's research program Extremes excels in this regard, involving stakeholders in the selection process of projects to be funded. The ETH-Domain-wide Joint Initiatives in the Strategic Area of Engagement and Dialogue with Society require a high degree of stakeholder involvement at all stages. WSL will lead one of the joint projects and actively contribute to two others.

Personal exchange between researchers and members of politics and society is becoming increasingly important in times of major crises. This highlights the need as a research institute to invest substantially in the dialogue forms of knowledge transfer. WSL is committed to expanding its pool of experts in science communication and promoting dialogue skills in the next generation of scientists. This exchange with politics and society will, in return, reinforce the trust in and appreciation and support for WSL's work. The WSL Directorate established several new measures in 2022 to encourage dialogue forms of knowledge transfer: (1) an "implementation track" in the WSL internal call for innovative projects, (2) consideration of additional indicators of societally relevant activities in the yearly MbOs, and (3) internal courses on the science–policy interface, such as Politics Bootcamp, where young researchers learn about Swiss politics and its mechanisms.

8.6 Methodological opportunities

WSL has a long tradition of developing and adopting newly emerging methodological developments in its research. Recent examples are the integration of autonomous sensor platforms and artificial intelligence (AI) technologies into data collection, assessment and analysis procedures (Section 5). WSL is often at the forefront in testing new methods and approaches, thanks to its long-term monitoring and experimental sites, its large-scale field infrastructure, and its many laboratories with unsurpassed infrastructure and high technological standards. WSL's unique combination of infrastructure also means that the research institute is able to take advantage of new methodological opportunities.

Some important key activities for the near future, where initial steps have already been taken, include establishing advanced inventorying and monitoring systems; applying ground-, drone-, and remote-sensing-based methods; advancing new sensor technologies; using (e)DNA and X-omics in environmental analyses; developing software and code or AI-based methods to collect, quality control and analyze data in a high-performance computing environment; and combining available methods for near-real-time risk assessments of natural hazards and ecological risk assessments. Some concrete examples of promising methodological developments that WSL plans to explore and apply in its research activities include:

Next-generation process-based research – environmental X-omics: Molecular mechanisms of acclimation and (evolutionary) adaptation are central in the adjustment of organisms to a rapidly changing environment. They will be assessed by characterizing epigenetic effects and applying X-omics, e.g., transcriptomics, metabolomics and isotopomics, in non-model organisms (most species in natural environments). This work includes analysis of the microbiome of soils and plants, as well as the diversity of the ecosystem mesofauna, by applying novel techniques, such as environmental proteomics and large-scale eDNA assessments, to bridge scales from the ecosystem to the landscape.

Ecological nowcasting and risk forecasting: Real-time data transfer and on-the-fly data quality control and aggregation (e.g., Treenet) are currently implemented at WSL. These approaches will be complemented by close-to-real-time automated measurements of ecosystem responses to environmental drivers (focusing on extremes) combined with mechanistic models (model–data fusion in Bayesian frameworks) to acquire accurate real-time information on the state and functioning of ecosystems at high spatial and temporal resolutions. The combination of a range of observation-based methods and approaches with innovative modeling approaches will provide indicators for regime shifts and critical ecosystem transitions, thereby helping to define at-risk areas, and will make it possible to adjust management approaches in order to maintain ecosystem services.

Natural hazard risk assessment: Through the assimilation of remotely sensed, process-based variables into high-resolution numerical models over complex terrain, it will be possible to generate detailed risk forecasts for natural hazard management, including for extreme events, at unprecedented temporal and spatial scales. While most of the elements of such a prediction chain already exist, true progress in this area will require the clever combination of the available infrastructure, process understanding and modeling tools.

Refined projections of cryospheric changes and the resulting impact: The availability of environmental data has recently exploded in every domain, fueled by technological developments in remote sensing, in situ data acquisition and transmission, and autonomous sensing. Such data is particularly relevant for environmental compartments undergoing rapid changes, such as the cryosphere. The combination of new data with modern methods of analysis is key for a new generation of projections regarding the impacts of such changes. Amongst these are altered water availability in regions dominated by snow and glaciers, changes in stability and nutrient cycles in areas affected by permafrost, and global sea level rise related to glacier loss.

8.7 Options for implementation

The implementation of the above-mentioned new opportunities for WSL will be concretized through the development and planning processes described in Sections 2.5, 2.6 and 3. Decisions about these opportunities will be in line with WSL's overall financial planning, taking into account the expected tightening of the financial situation within the ETH Domain (Section 4.2.3), as well as the planning in the thematic areas laid out in Section 5. It is expected that the financial scope for establishing new WSL programs or initiatives will be limited. Nevertheless, WSL is committed to addressing the new opportunities laid out above, within its means, and therefore plans to initiate one new program in 2023, on ecological transition in complex systems (Section 8.4).

A number of other focused measures will also be taken. Creating new long-term positions, by reallocating or reorienting positions that become available from upcoming retirements, is one of the most effective and long-term means to strengthen competences and pursue the opportunities described above. Specific topics, e.g., urban ecology, can be emphasized in a targeted manner by bundling the activities in a new research group. Another option for implementing such activities is dedicated engagement in the Joint Initiatives of the ETH Domain (Section 2.5), which offer topic-specific internal calls for projects. A call on the topic of health is expected to be launched between mid-2023 and mid-2024 within the ETH Domain.

Over the mid-term, the opportunities outlined above will be elaborated further regarding their integration into WSL's next strategic plan for 2025–2028. Finally, in the short term, the opportunities can be pursued by incorporating relevant aspects and activities into the annual target agreement discussions between the WSL Director and the heads of the research units.

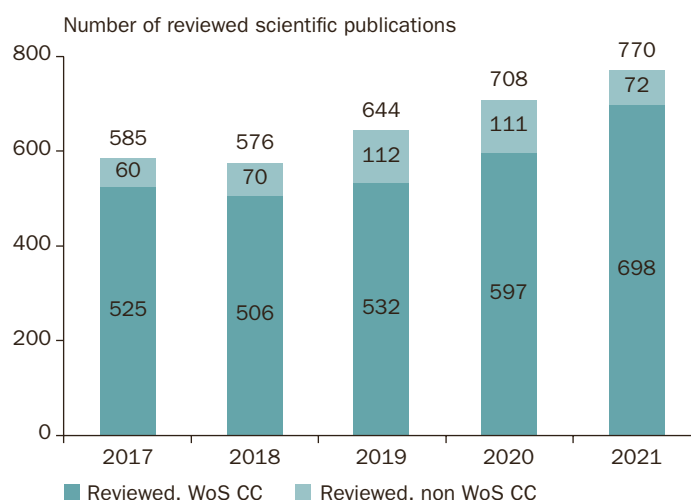
Appendix I: Facts and Figures

1. Research

Publications

The number of peer-reviewed scientific articles by WSL authors, published in journals indexed in the Web of Science Core Collection (WoS CC), reached a record of 698 in 2021. Since 2017, this number has been increasing at an average rate of 10% per year.

In addition, WSL authors publish 60 to 120 peer-reviewed publications in journals not indexed in WoS CC. These scientific publications include several reference works targeting an academic or non-academic audience, such as a report on the “Extreme flood events on the River Aare” and the book “State of Europe’s Forests 2020”.

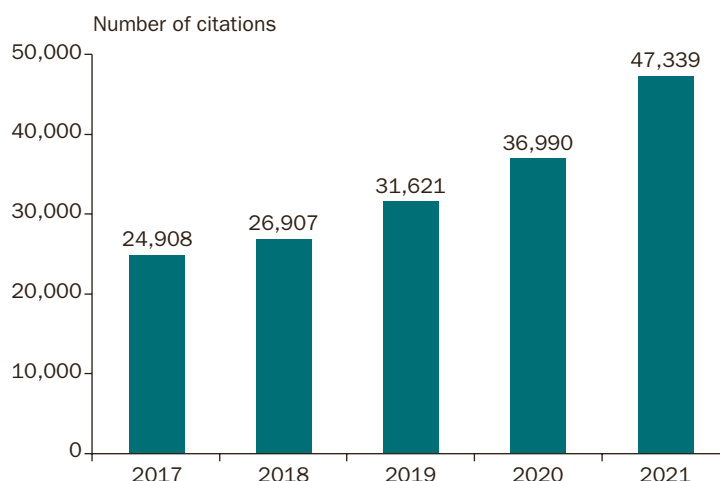


Citations

There has been steady growth in the number of citations of peer-reviewed scientific articles by WSL authors published in journals indexed in WoS CC.

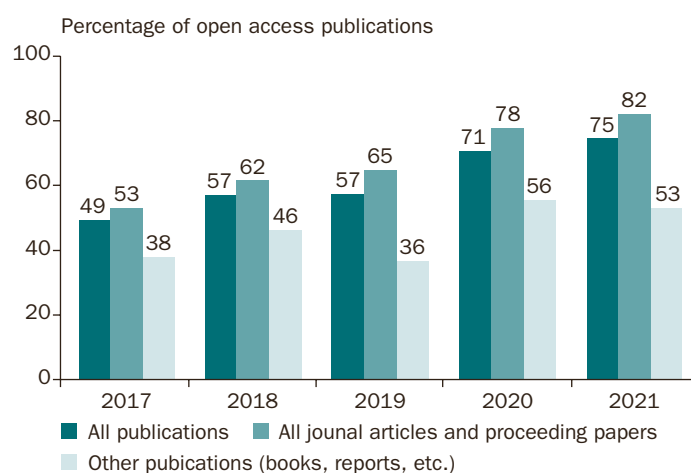
The almost 47,000 citations in 2021 represent nearly a doubling in the past 5 years. The large number of citations is an indication of the substantial impact of WSL research/publications in the scientific community.

Since 2017, two to three WSL researchers have been included in the Web of Science’s list of Highly Cited Researchers. This list includes researchers with multiple highly cited papers that rank in the top 1% by citations for a given field and year in the Web of Science.



Open access

In the last five years, the percentage of WSL publications available as “open access” has increased considerably. This concerns not only articles published in scientific journals but also other types of publications, such as books and reports published by WSL and other editors. The percentage of all journal articles and proceeding papers published as “open access” increased from 53% to 82% in the last five years, while there was an increase from 38% to 53% for other publications.



Success in ERC calls

Since 2017, three WSL female researchers have been granted a highly prestigious European Research Council (ERC) personal grant, supported with a total of over 6.5 million Euro.

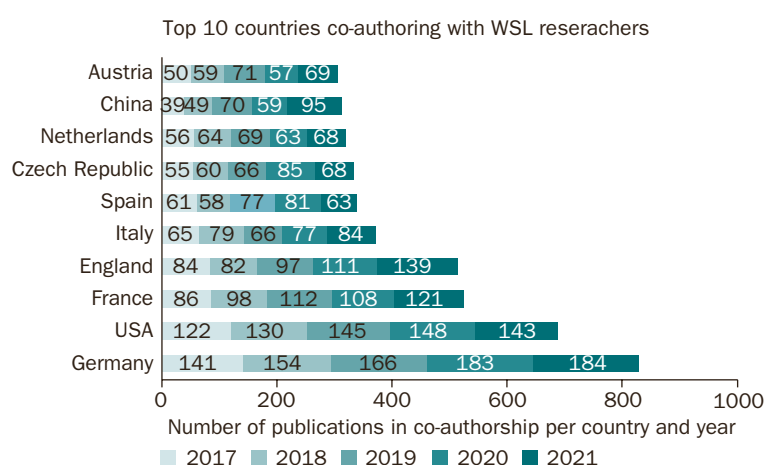
For instance, a WSL genetics researcher received one of the 2020 ERC Consolidator Grants for the participatory science project MyGardenOfTrees. In the past five years, WSL has had an overall success rate of about 23% in ERC Grant calls.

Call	Funding scheme	Start date	EU contribution in Mio Euro
ERC-2017-ADG	Advanced Grant	01/10/2018	2.5
ERC-2017-COG	Consolidator Grant	01/05/2018	2.0
ERC-2020-COG	Consolidator Grant	01/06/2021	2.0
Total			6.5

International collaboration

WSL's publications are predominantly done in collaboration. Every year, WSL researchers publish work with colleagues from about 100 different countries.

WSL researchers mostly collaborate with institutions from Western and Central Europe and the United States of America. However, the importance of collaborations with colleagues from Asian institutions is steadily increasing.

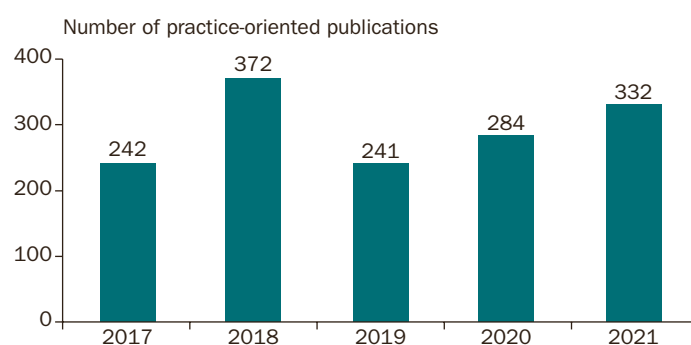


2. Knowledge transfer (KTT) and outreach

Practice-oriented publications

Practice-oriented publications include articles, books, reports and brochures, which usually target practitioners and are often published in two or three national languages. This category also includes a few non-reviewed scientific publications, such as proceeding papers. Overall, WSL strives for a balance between practice-oriented and scientific publications.

The volume of WSL's practice-oriented publications varies from year to year. The years 2018 and 2021, however, show a steep increase, with 372 and 332 publications, respectively. These large numbers are partly due to the publication of many proceeding papers in the "International Snow Science Workshop Proceedings" in 2018 and of several book chapters in "Le selve castanili della Svizzera italiana" in 2021.



Cooperation with the private and public sectors

In 2021, WSL signed 30 new collaboration contracts with the public sector and 5 with private partners, with a value of > CHF 50,000 per contract.

Several contracts with the public sector allow WSL not only to carry out its national tasks, but also to provide many other services to society, such as the development of avalanche hazard maps for an alpine canton or the assessment of the attitude of the Swiss population towards forests.

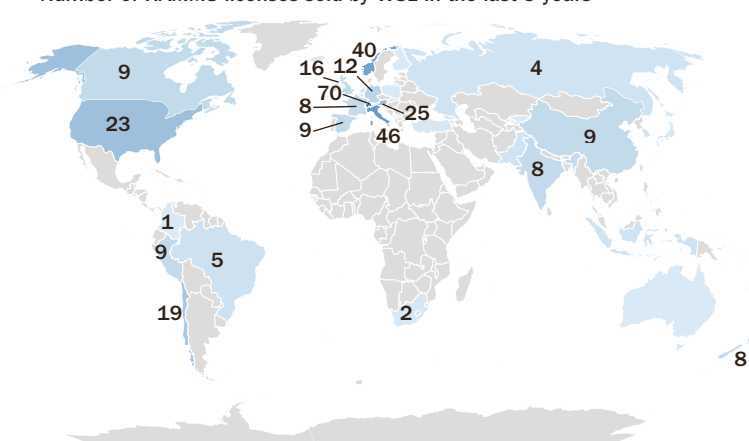
	Number of contracts				
Collaboration contracts	2017	2018	2019	2020	2021
Collaboration contracts with the private sector (>CHF 50,000)	5	5	2	3	5
Collaboration contracts with the Swiss public sector (>CHF 50,000)	31	27	48	36	30
Total	36	32	50	39	35

Technologies and licenses

In the last 5 years, WSL registered 2 patents, 1 spin-off company, and 367 licenses.

The licenses are mainly related to the use of the RAMMS software suite. This software contains various independent modules for modeling rapid mass movements in alpine terrain, such as avalanches, debris flows and rockfall. Additionally, a new exclusive license for intellectual property rights was signed in 2021 with the company TerraRad Tech, the first WSL spin-off, which was founded in 2020.

Number of RAMMS licenses sold by WSL in the last 5 years



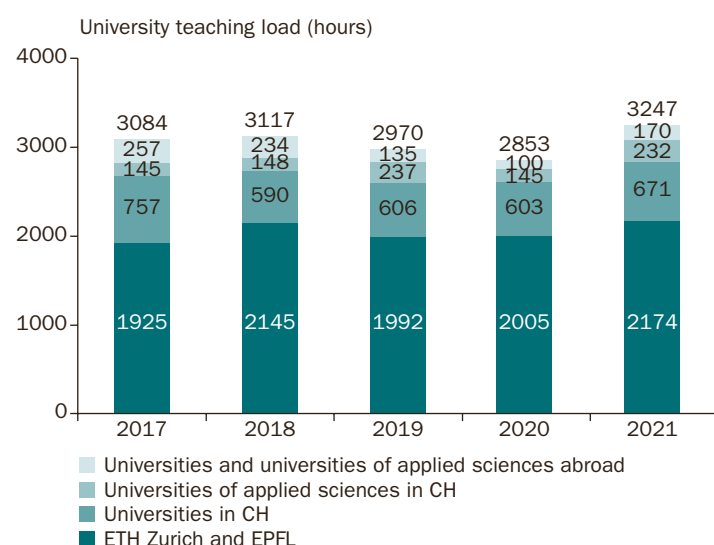
3. Teaching and student supervision

Teaching at universities

In the past five years, the total number of teaching hours held by WSL employees at universities fluctuated between 2850 and 3250 per year. On average, 67% of WSL teaching hours were held at ETH Zurich and EPFL.

The teaching load for WSL employees at universities of applied sciences fluctuated between 5% and 8% of the total WSL teaching hours over the past five years.

Yearly, more than 100 WSL employees contribute to the WSL university teaching load, with about 20–25% of the contributions made by female staff.



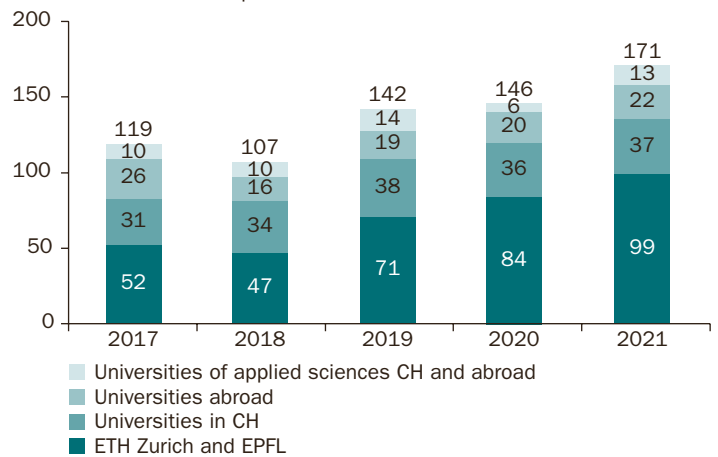
Student supervision

WSL contributes to education at the academic level by supervising bachelor's, master's, diploma and PhD students in Switzerland and abroad.

The number of bachelor's and master's students supervised by WSL staff varied between 107 and 171 in the last five years. With a share of 73%, supervised master's theses dominated in 2021.

On average, 51% of these students were matriculated at ETH Zurich and EPFL, and 47% of the WSL-supervised students were female.

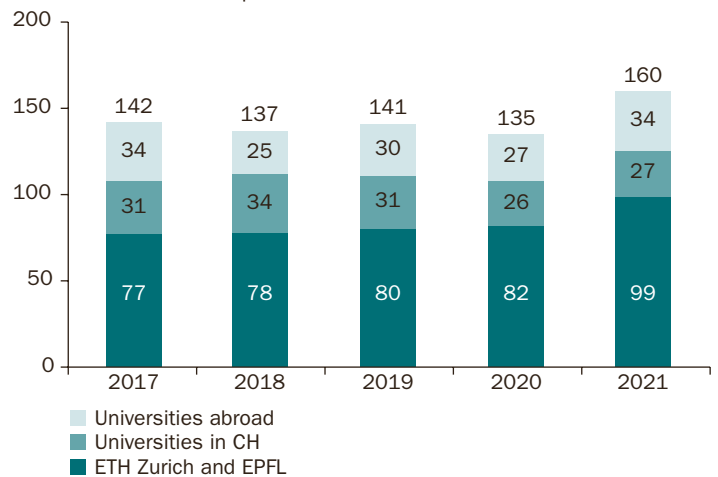
Number of WSL-supervised bachelor's and master's students



The number of PhD students supervised by WSL staff fluctuated between 135 and 160 over the last five years. The percentage of WSL-supervised PhD students who were matriculated at ETH Zurich or EPFL increased from 54% to 62%, with constant growth over the years.

In 2021, 49% of the WSL-supervised PhD students were female.

Number of WSL-supervised PhD students



Professors and "PrivatdozentInnen"

At the end of 2021, WSL had 28 employees with a professor title from universities in Switzerland or abroad. This encompasses four ordinary professors, four assistant professors, two associate professors and 18 honorary professors. Nine employees with an honorary professorship were from universities abroad (Europe, North America, Asia). Additionally, six WSL researchers held the academic title of "Privatdozent" with a *venia legendi* at the ETH Zurich and at the Universities of Zurich, Bern or St. Gallen.

Number of professors and "PrivatdozentInnen"

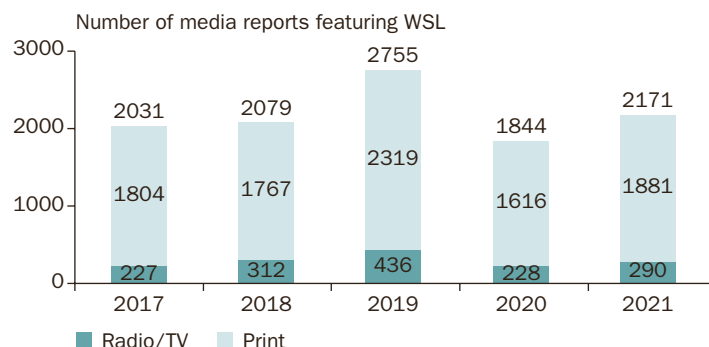


4. Outreach to society and politics

Media presence

WSL is regularly featured in various media (print, radio, television, internet, apps and social media). With 2171 contributions reporting about WSL activities, the media coverage in 2021 was similar to that in previous years. The year 2019 was an exception, with 2755 features, likely because of the extraordinary avalanche situation in January and the avalanche on a ski slope on the Plaine Morte in Crans-Montana in February.

Media reporting includes the most important national and international newspapers, as well as radio and TV news emissions in Switzerland.



5. Finances

Financial contribution from the federal government

The financial contribution from the federal government for the last five years includes the basic contribution; credit transfers, which are strategic contributions from the ETH Board for the Competence Center Environment and Sustainability (CCES), the Strategic Focus Areas, and the Blue-Green Biodiversity Research Initiative; and investments for buildings.

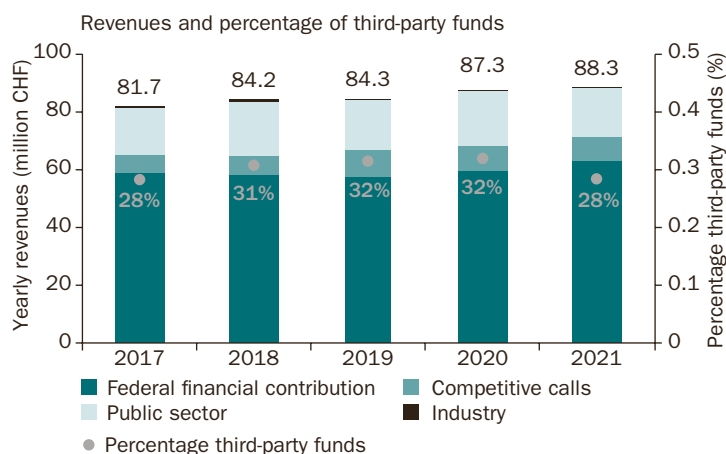
Half of the funding for avalanche warning was previously financed by FOEN, but it has been included in the federal financial contribution since 2021.

	million CHF				
Federal financial contribution	2017	2018	2019	2020	2021
Basic contribution	57.5	57.0	55.0	56.7	53.5
Credit transfers ETH Board		0.0	0.1	1.2	2.6
Transfer avalanche warning					2.7
Investments for buildings	1.2	1.2	2.6	1.4	4.4
Total federal financial contribution	58.7	58.3	57.7	59.4	63.2

Revenue

The yearly revenue includes the federal financial contribution and funding from various third parties from competitive calls (e.g., SNSF, Innosuisse, EU), the public sector and foundations (e.g., federal offices, Cantons), and industry. In addition (not included in graph), WSL generates revenue (about CHF 2 million per year) through its own activities (e.g., sale of licenses, conference fees).

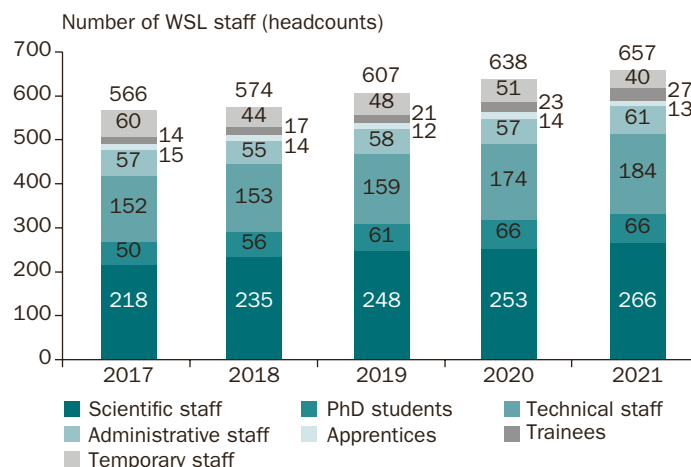
The revenue increased slightly and the percentage of third-party funds fluctuated between 28% and 32% of the total revenue over the past five years.



6. Personnel

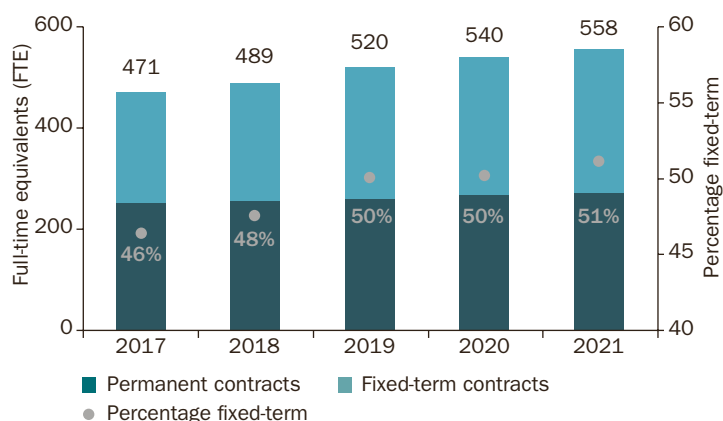
Staff structure (headcounts)

The end-of-year composition of WSL staff in terms of headcounts is depicted for 2017–2021. In 2021, scientific staff comprised 332 employees (289 full-time equivalents, FTE), including 66 PhD students and 49 postdocs. A total of 184 employees (153 FTE) were technical staff and 61 employees (45 FTE) were administrative staff (including HR, finance and communication specialists). WSL also employed 13 apprentices and 67 people with short-term contracts as trainees or assistants on a project basis.



Percentage fixed-term and permanent employment (full-time equivalents)

The end-of-year number of WSL staff employed with fixed-term and permanent contracts, expressed as full-time equivalents (FTE), is depicted for 2017–2021. The percentage of fixed-term contracts increased from 48% to 51% in the last five years. However, WSL strives to maintain a balanced ratio between permanent and fixed-term employment to maintain flexibility and ensure the availability of long-term expertise.

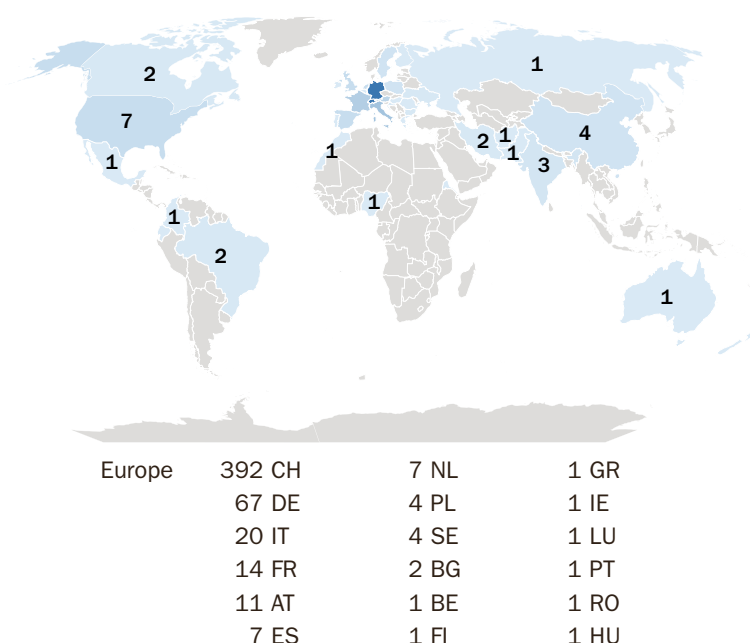


Nationalities

The percentage of foreign WSL employees was 32% at the end of 2021. This percentage remained stable between 2017 and 2021. Among the scientific staff, the share of foreigners was around 47% at the end of 2021. WSL staff came from 39 different countries, with 144 employees from EU countries and 43 from other countries.

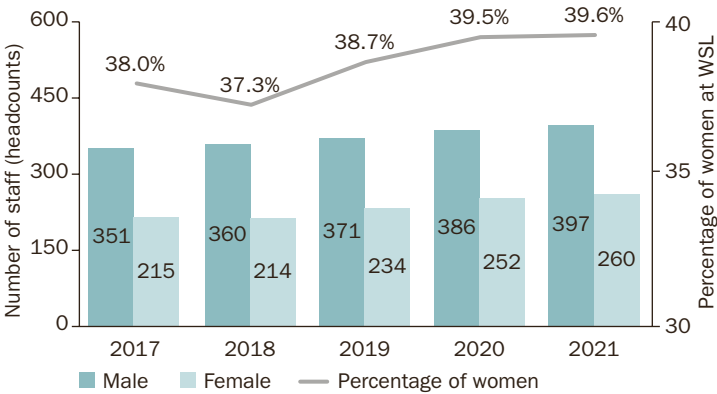
German is the mother tongue of most WSL employees (80%). The most spoken native languages after German are French, Italian, English and Spanish.

WSL staff nationalities 2021



Percentage of women at WSL

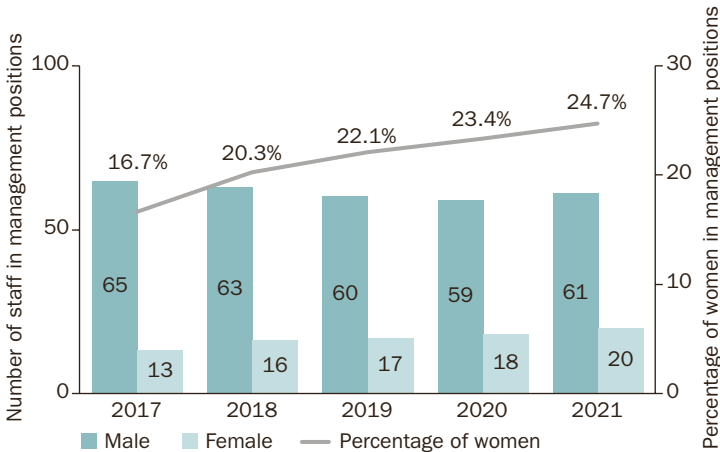
The end-of-year number and percentage of women employed at WSL in terms of headcounts is depicted for 2017–2021. The percentage of women increased from 37.3% in 2018 to 39.6% in 2021. In 2021, the percentage of women was about 37% for scientific staff (44% for PhD students and 43% for postdocs), 27% for technical staff (including diverse functions in research and support units), and 81% for administrative staff.



Percentage of women in management positions

The end-of-year percentage of women in management positions (Directorate, heads of research and support units, heads of groups and programs) increased from 16.7% in 2017 to 24.7% in 2021.

WSL aims to have at least 28% women in management positions by the end of 2024, while targeting 30%.



Appendix II: WSL Legal Mandate

This Appendix II summarizes important legal background information defining WSL's legal mandate and the strategic planning, which are referred to in Section 2 of this self-assessment report. Only the parts relevant to WSL are included here. References to the corresponding sources available online are included. Some of them are only available in one of the Swiss national languages, but not in English. As English is not an official language of the Swiss Confederation, the English formulations and translations in this document are provided for information purposes only and have no legal force.

Legal foundation of the ETH Domain

The Federal Act on the Federal Institutes of Technology (ETH Act) of 4 October 1991 is the legal foundation of the ETH Domain, in which the Confederation specifies the constitutional mission of running the Federal Institutes of Technology (ETH Zurich, EPFL) while at the same time creating the legal framework for the operation of the research institutions of the ETH Domain (PSI, WSL, Empa and Eawag). The ETH Act regulates the competencies divided among the Parliament, Federal Council, the ETH Board and the six institutions. In particular, it outlines the position, structure and tasks of the ETH Domain and institutes the ETH Board as the strategic management body.

ETH Act (4.10.1991) (as of 1 January 2022)

Also relevant in this context:

Ordinance on the Domain of the Swiss Federal Institutes of Technology (Ordinance on the ETH Domain) of 19 November 2003 (as of 1 May 2017).

Foundation for strategic planning

The ETH Board, which is responsible for the strategic management of the ETH Domain, formulates the ETH Domain's strategy for a performance period, in dialogue with the institutions of the ETH Domain, and supervises its implementation.

Art. 25 para. 1 let. a,d ETH Act (4.10.1991) (as of 1 January 2022):

- ^a The ETH Board shall establish the strategy of the ETH Domain within the scope of the strategic objectives of the Federal Council;
- ^d The ETH Board shall approve the development plans for the ETH Domain and monitor their implementation.

Art. 12 Para. 1 Ordinance on the Domain of the Swiss Federal Institutes of Technology (Ordinance on the ETH Domain) of 19 November 2003 (as of 1 May 2017)

- ¹ The ETH Board bases the formulation of the target agreements with the two federal institutes of technology and the research institutes on the specifications of the strategic objectives and on the payment framework. In doing so, it takes into account its strategic planning and the development plans of the ETHs and the research institutes.

Purpose of ETH Domain institutions

The purpose of the institutions in the ETH Domain is, as written in Article 2 of the Federal Act on the Federal Institutes of Technology from 4 October 1991:

Art. 2 Purpose, ETH Act (4.10.1991) (as of 1 January 2022):

- 1 The two federal institutes of technology and the four research institutes within the ETH Domain shall:
 - ^a educate students and specialists in scientific and technical fields and ensure continuing education and training;
 - ^b expand scientific knowledge through research;
 - ^c support junior scientific staff;
 - ^d provide scientific and technical services;
 - ^e ensure a dialogue with the public;
 - ^f exploit their research findings.
- 2 They shall take account of Switzerland's needs;
- 3 They shall discharge their remit at an internationally recognized level and encourage international cooperation;
- 4 The guiding principles for teaching and research are respect for human dignity, responsibility in the use of natural resources and the environment together with an evaluation of the consequences of technological applications.

Autonomy and duties of research institutes

The autonomy and the duties of the ETH Domain research institutes are, as written in Article 21 of the Federal Act on the Federal Institutes of Technology from 4 October 1991:

Art. 21 Autonomy and tasks, ETH Act (4.10.1991) (as of 1 January 2022):

- 1 The four research institutes within the ETH Domain (EMPA, EAWAG, PSI and WSL) are autonomous public-law entities established by the Confederation and have their own legal personality;
- 2 They shall conduct research within their specified field and provide scientific and technical services;
- 3 To the extent of their capacities, the four research institutes within the ETH Domain shall make themselves available to higher education institutions for the purpose of teaching and research.

Mandate WSL

According to Article 3 of the Regulations of the ETH Board concerning the research institutes of the ETH Domain from 13 November 2003, WSL has the following mandate:

Art. 3 WSL, Ordinance of the ETH Board on the Research Institutes of the ETH Domain (13.11.2003) (as of 20 January 2004):

- 1 WSL is active in sustainable spatial development, in particular development in mountain areas and in conurbations, in the following specialist areas:

- ^a landscape research;
 - ^b forest ecology and forest management;
 - ^c natural hazards and integral risk management;
 - ^d snow, ice, avalanches and permafrost.
- 2 As a specialist agency, WSL shall provide the following services within the scope of its capabilities:
- ^a It shall ensure the provision of an avalanche warning service in Switzerland and inform the public about the avalanche danger.
 - ^b It shall operate the Swiss Forest Health Service in accordance with Article 30 paragraph 2 of the Forest Ordinance of 30 November 1992.
 - ^c It shall ensure the scientific and technical supervision of forest plant protection in accordance with Article 44 of the Plant Protection Ordinance of 28 February 2001.

Tasks assigned by the federal government

In addition to the basic mandate, WSL is mandated by federal legislation to provide a range of national services related to the terrestrial environment. [...] It thus provides, to the greatest extent possible, the following services:

(i) Running the Swiss National Forest Inventory, the monitoring of Swiss Natural Forest Reserves, and the Long-term Forest Ecosystem Research program

Art. 37a paras. 2 and 3 Forest Ordinance of 30 November 1992 (as of 1 January 2020):

- [1 The FOEN is responsible for the collection of survey data on the forest.]
- 2 In cooperation with the WSL, it surveys:
 - ^a by means of the National Forest Inventory, the basic data relating to the locations, functions and condition of the forest;
 - ^b the long-term development processes in natural forest reserves.
- 3 As part of its basic remit, the WSL shall conduct long-term research programs to survey the pressure on the forest ecosystem.
- [4 The FOEN shall inform the authorities and the general public about these surveys.]

(ii) Providing the avalanche warning service for Switzerland and informing the public about avalanche danger

Art. 23 para. 1 let. a-d Ordinance on Civil Protection of 11 November 2020 (as of 1 January 2021)

- 1 The following federal natural hazard agencies are responsible for issuing warnings in the case of the following events:
 - [^a MeteoSwiss: for dangerous weather events;]
 - [^b the FOEN: for floods, landslides and forest fires;]
 - ^c the WSL Institute for Snow and Avalanche Research: in the event of avalanche danger;
 - [^d the SED: in the event of earthquakes.]

Art. 3 Para. 2 Bst a, WSL, Ordinance of the ETH Board on the Research Institutes of the ETH Domain (13.11.2003) (as of 20 January 2004):

- 2 As a specialized body, WSL provides the following services within the scope of its capabilities:
 - ^a It ensures the provision of an avalanche warning service in Switzerland and informs the public about the avalanche danger.

(iii) Running the Swiss Forest Health Service

Art. 30 Para. 2 Forest Ordinance of 30 November 1992 (as of 1 January 2020):

- 2 The Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) has the following tasks:
 - ^a it organizes, together with the cantonal forestry services, the collection of data of relevance to forest protection;
 - ^b it provides information about the occurrence of harmful organisms and other factors that may damage the forest;
 - ^c it advises the cantonal forestry services in matters of forest protection.

(iv) Providing scientific and technical support for forest health protection

Art. 103 Plant Health Ordinance of 31 October 2018 (as of 1 January 2020):

The Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) is responsible for the scientific and technical aspects of plant health in the forestry sector.

Art. 3 Para. 2 Bst c, WSL, Ordinance of the ETH Board on the Research Institutes of the ETH Domain (13.11.2003) (as of 20 January 2004):

- 2 As a specialized body, WSL provides the following services within the scope of its capabilities:
 - ^c It ensures the scientific-technical supervision of forest plant protection according to Article 44 of the Plant Protection Ordinance of 28 February 2001.

Art. 72c of the Plant Protection Products Ordinance of 12 May 2010 (as of 1 July 2022):

The Federal Office for Agriculture (FOAG), with its federal agricultural research institute (Agroscope), and the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) shall assess:

- ^a the effectiveness of plant protection products against harmful organisms and the effects on plants and plant products;
 - ^b the effects of the plant protection products on non-target species, on soil fertility and on bees in the treated agricultural areas.

Appendix III: Short Summary of the Work of the WSL Advisory Board 2014–2022

The WSL Advisory Board (AB) was set up in 2014 at the initiative of the then Director Prof. Konrad Steffen. The purpose of the AB is not to carry out formal reviews of WSL but to provide an independent outside view of the scientific work, service operations, and knowledge and technology transfer, advise the WSL Directorate on strategic issues, and be available as a sounding board for current and future activities. The AB members are selected by the WSL Director and come from different international and national institutions. The AB meets usually once a year for a 1.5 to 2-day meeting at one of the WSL locations. It provides the WSL Directorate with a brief report about its deliberations, findings and recommendations. The AB report is an internal document, and the Directorate formally responds to it in preparation of the next AB meeting.

Here, the WSL AB provides a brief historical overview of its work since 2014. This summary is prepared at the request of the WSL Directorate and will be a contribution to the Self-Evaluation Report that the WSL prepares for its formal review in November 2022.

In total six sessions of the AB have taken place since 2014. In the following these sessions and the recommendations of the WSL AB are briefly revisited. This summary also highlights how the interaction of the AB and WSL evolved into a productive partnership.

Session 1: WSL Birmensdorf, 27.-28. November 2014

The inaugural meeting served to introduce to the AB the network of interconnected infrastructure of WSL that is unique and forms the basis on which the scientific, service and KTT activities are developed and carried out. Short presentations by the Director and leading staff focused on forest, biodiversity, landscape, and socio-economic science. The AB noted the strong background available in terms of expertise, quality of the equipment, scientific dynamism, and visible production of WSL. This forms a large potential to develop a unique center of excellence around some important and timely questions for the near future.

The AB recommended (i), to develop a short research plan for the Swiss Forest Lab; (ii) a more coordinated approach to the economic and social science activities focusing on natural hazards and adaptation to climate change; (iii), a clear strategy towards climate change; (iv), strengthening the interface between forest management and agriculture, towards a forest-based bio-economy, and (v), a stronger engagement in international assessments such as IPCC and IPBES. Furthermore, the development of an explicit strategy of open data and data management was recommended.

Session 2: WSL/SLF Davos, 3.-4. March 2016

The focus of this meeting was to discuss WSL's activities at the Institute for Snow and Avalanche Research at Davos (SLF). Introductions by the WSL Director and the SLF Director were followed by presentations on mountain ecology, mass movements, snow physics, permafrost, and operational avalanche assessment and warning. The AB noted the high quality of the fundamental and applied research at SLF that stems from its long tradition of internationally recognized research on snow and avalanches. Since its integration into WSL, SLF has extended its research portfolio.

In its report the AB recommended (i), to strengthen internal projects that foster interactions and interdisciplinary links between research units at WSL and SLF; (ii), to consider the closer affiliation of mountain ecosystems research to Davos; (iii), to develop a combined approach of snow hydrology and permafrost; (iv), to utilize the scientific potential of a stronger interaction between mass movement and avalanche research; (v), a strategic development of the

cooperation with the Canton of Grisons towards a competence center of international stature; and (vi), harvest the unique opportunity of having the basic research on avalanche and the operational avalanche service under one roof. The AB also realized that its feedback to WSL would be substantiated by defining the focal topics in advance of sessions. In response, WSL adopted the distribution of excellent preparatory material for AB sessions.

Session 3: WSL Field Stations in the Valais, 25.–27. October 2017

WSL invited the AB to the Canton of Valais where WSL operates key research sites on natural hazards. Presentations on three WSL Strategic Initiatives (SI) were given: 1. the Swiss Forest Lab, including the large-scale irrigation experiment at Pfynwald, 2. Climate Change Impacts on Alpine Mass Movements, including rock fall and debris flow research in the Illgraben and powder snow avalanche measurements in the Vallée de la Sionne, and 3. EnviDat, including the WSL Data Policy. The AB noted the unique science opportunity of such natural laboratories that are equipped with the latest measurement and monitoring devices.

The AB commended the WSL Directorate for the introduction of the new instrument of “WSL Strategic Initiative” which is supported with CHF 3 M. This is a unique instrument to boost internal scientific collaboration, foster excellence and enhance output at the international level. Specific advice was given by the AB for the three initiatives. The SI Swiss Forest Lab would benefit from (i), a greater integration of policy questions and cooperation with the relevant federal offices and Cantons; (ii), clear criteria for membership in the network; and (iii), benchmarking with similar initiatives in other countries, particularly in the European framework. The SI Climate Change Impacts on Alpine Mass Movements could be the seed for a National Research Program. Further recommendations for this SI were (i), to include glacier melt and glacial lake formation; (ii), consideration of connecting to, or developing into, an international research program; and (iii), to strengthen the cooperation with relevant Cantons on natural hazards. For SI EnviDat, the AB recommended that (i), real and not only meta data should be hosted; (ii), scientists need to be continually involved in the development and evolution of the data base; and (iii), a clear policy of data management and a strategy of storage infrastructure, potentially in collaboration with other institutions, should be developed.

Session 4: WSL Birmensdorf, 24.–26. April 2019

The focus of this session was the new Strategic Initiative on Extremes and the topic of equal opportunity and career development at WSL. The AB strongly supports the addition of this new SI which addresses a topic that is of key relevance to the Alpine environment and its future. The SI can build on the existing expertise available at WSL, including SLF, and the emphasis on ecosystem impacts seems ideal for WSL. During a visit to a former military underground storage WSL's subfossil wood collection was shown. Entire wood stumps dating from the last deglaciation were secured from building excavation sites in Zurich and represent an invaluable asset for dendrochronological research.

The following recommendations for the new SI were communicated: (i), exploration of the full richness of extreme events, including compound events, and multiple interacting drivers; (ii), embedding the SI Extremes into the five existing research pillars of WSL to mobilize synergies; (iii), addressing in near-real time extreme events, following the successful example of the 2018 drought; and (iv), strengthening the collaborations with ETH and universities on this emerging topic.

Regarding equal opportunity, the AB congratulates WSL for the appointment of a woman to the Directorate and hopes that WSL at all levels works towards increasing the number of women. Among the AB recommendations were: (i), to increase the visibility of women in leadership roles; (ii), to improve the mentoring program, including flexibility for senior

scientists; and (iii), to implement an assessment process on the progress in equal opportunity efforts. The mentoring of early career scientists and PhD students was also discussed and the AB recommends: (i), to consider external representation on PhD committees; (ii) to support bottom-up activities of the PhD student organization; and (iii), to strengthen the structure of graduate formation through annual meetings or workshops, development seminars and exposure opportunities. In addition, the AB emphasized the importance of generating reliable data to track progress in these critical areas.

The AB expressed its appreciation for the responsiveness of WSL to prior recommendations and noted the positive impacts. Discussions with the AB and WSL Directorate continue to be open, constructive and collegial.

Session 5: Virtual AB meeting via zoom on 20. October 2021

Due to the Covid-19 situation and the tragic loss of the WSL Director Prof. Konrad Steffen in August 2020, no AB meeting took place in 2020. Due to the recurring Covid situation a short virtual meeting was convened on 20. October 2021. This was the opportunity to meet the new WSL Director Prof. Beate Jessel who presented the latest developments at WSL. An important milestone was reached by the foundation of the new “Climate Change, Extremes and Natural Hazards in Alpine Regions Research Centre”, CERC, at Davos. This is a partnership of WSL with the Canton of Grisons that enables the establishment of two new professorships. The new Director also announced the implementation of a rotation system for AB membership.

Session 6: WSL/SLF Davos, 21.–22. June 2022

This AB session took place two days prior to the international symposium “The Cryosphere in a changing climate – A scientific symposium in the memory of Koni Steffen”. The focus of the session was the provision of AB input to the comprehensive international evaluation of WSL that was mandated by the ETH Council and scheduled for November 2022. The WSL Directorate provided an update on the five ongoing Strategic Initiatives and presented initial ideas for the strategic planning. The preparation process for the forthcoming international evaluation was explained.

The AB noted the challenging period of the past two years and commended the interim leadership on maintaining the excellent scientific output and service under difficult conditions. In its report the AB made seven overarching recommendations: (i), combining the expertise in the WSL leadership across the board from scientific excellence, administrative expertise, institutional knowledge, and service orientation; (ii), managing the change in leadership of the unit Forest Dynamics by observing the complementary tasks of science and service; (iii), using the forthcoming review to strengthen the WSL community by engaging all levels; (iv), developing a long-term vision of WSL under the new leadership; (v), using the unique opportunity of the inaugural funding for the new Director to develop a research program that integrates with, and enhances, ongoing activities; (vi), clarify the structure of WSL-SLF-CERC, including the new professorships; and (vii), reflect on the role of the AB in the future. In addition, the AB has delivered practical input to the WSL Directorate for the preparation of the international evaluation process.

Eric Brun, Erwin Dreyer, John Innes, John Gowdy, Josef Hess, Sandra Lavorel, Thomas Painter, Paul Steffen, Thomas Stocker, Monica Turner, Christian Wilhelm

Bern, 11. August 2022

Thomas Stocker (AB Chair 2022)

Eric Brun, Erwin Dreyer, John Innes, John Gowdy, Josef Hess, Sandra Lavorel, Thomas Painter, Paul Steffen, Monica Turner, Christian Wilhelm

Appendix IV: List of Abbreviations

AI	artificial intelligence	FAIR	findability, accessibility, interoperability and reusability
ARE	Federal Office for Spatial Development	FAO	Food and Agriculture Organization of the United Nations
AUS	unmanned aerial system	FIBL	Research Institute of Organic Agriculture
AWN	Department of Forests and Natural Hazards, Canton Grisons	FOAG	Federal Office for Agriculture
BGB	Blue-Green Biodiversity Research Initiative	FOEN	Federal Office for the Environment
BSTB	Federal Civil Protection Crisis Management Board	FoLAP	Forum Landscape, Alps, Parks (SCNAT)
CAS	Certificate of Advanced Studies	FOPH	Federal Office of Public Health
CCAMM	Climate Change Impacts on Alpine Mass Movements	GCOS	Global Climate Observing System, Switzerland
CCES	Competence Center Environment and Sustainability	GDC	Genetic Diversity Centre, ETH Zurich
CERC	Climate Change, Extremes and Natural Hazards in Alpine Regions Research Centre	GLP	Global Land Project
CHELSA	Climatologies at High Resolution for the Earth's Land Surface Areas	GTN-P	Global Terrestrial Network for Permafrost
COST	European Cooperation in Science and Technology	GWG	Gebirgswaldpflegegruppe
CRYOS	Laboratory of Cryospheric Sciences, EPFL	HOMED	Holistic Management of Emerging Forest Pests and Disease
CSC	China Scholarship Council	HPC	high-performance computing
CWTS	Centre for Science and Technology Studies	IACS	International Association of Cryospheric Sciences
DNL	Datacenter Nature and Landscape	IALE	International Association for Landscape Ecology
DOI	digital object identifier	ICOS	Integrated Carbon Observation System
DORA	Digital Object Repository	ICP Forests	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
EAFV	Federal Institute for Forest Research	IGS	International Glaciological Society
Eawag	Swiss Federal Institute of Aquatic Science and Technology	INRAE	National Research Institute for Agriculture, Food and Environment, France
EAWS	European Avalanche Warning Services	IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
eDNA	environmental DNA	IPCC	Intergovernmental Panel on Climate Change
EGU	European Geosciences Union	IPSAS	International Public Sector Accounting Standards
EISLF	Swiss Federal Institute for Snow and Avalanche Research, Davos-Weissfluhjoch	IUCN	International Union for Conservation of Nature
eLTER	Integrated European Long-Term Ecosystem, critical zone and socio-ecological Research program	IUFRO	International Union of Forest Research Organizations
Empa	Swiss Federal Laboratories for Materials Science and Technology	KT	Knowledge and Technology Transfer
ENFIN	European National Forest Inventory Network	LABES	Swiss Landscape Monitoring program
EnviDat	Environmental Data Portal, WSL	LAINAT	Steering Committee for Intervention in Natural Hazards
EPFL	Swiss Federal Institute of Technology Lausanne (École polytechnique fédérale de Lausanne)	LID	Laboratory of Ion Beam Physics, ETH Zurich
ERC	European Research Council	LWF	Long-term Forest Ecosystem Research program
ESA	European Space Agency	MbO	Management by Objectives
ESKAS	Swiss Government Excellence Scholarships	MCPFE	Ministerial Conference on the Protection of Forests in Europe
ETH Zurich	Swiss Federal Institute of Technology Zurich (Eidgenössische Technische Hochschule Zürich)	MCS	mean citation score
EVOLTREE	EVOLution of TREEs as drivers of terrestrial biodiversity	MeteoSwiss	Federal Office of Meteorology and Climatology
		micro-CT	micro-computed tomography
		MNCS	mean normalized citation score

MOOC	Massive Open Online Course	SLF	WSL Institute for Snow and Avalanche Research SLF
MOSAic	Multidisciplinary drifting Observatory for the Study of Arctic Climate	SMOS	Soil Moisture and Ocean Salinity
MOU	memorandum of understanding	SNSF	Swiss National Science Foundation
NASA	National Aeronautics and Space Administration, USA	SPI	Swiss Polar Institute
NCCS	National Centre for Climate Services	SPPS	Swiss Federal Plant Protection Service
NFI	National Forest Inventory	SwissAIM	Advanced Inventorying and Monitoring System for Swiss Forests
NFZforest.net	Nancy-Freiburg-Zurich Forest Research Network	SwissTopo	Federal Office of Topography
NGO	non-governmental organization	TCS	total number of citations
OA	open access	ToR	term of reference
ORD	Open Research Data	UNDP	United Nations Development Programme
PD	Privatdozent	UNESCO	United Nations Educational, Scientific and Cultural Organization
PERMOS	Swiss Permafrost Monitoring Network	UNFCCC	United Nations Framework Convention on Climate Change
PGIM	permafrost and ground ice map	USDA	United States Department of Agriculture
PLANAT	National Platform for Natural Hazards	USYS	Department of Environmental Systems Science, ETH Zurich
PP top 10%	proportion of publications in the top 10% most cited publications	VDC	Virtual Data Center
PSI	Paul Scherrer Institute	WaMos	Sociocultural Forest Monitoring
RAMMS	Rapid Mass Movement Simulation software suite	WBS	Monitoring the Effectiveness of Habitat Conservation in Switzerland
SAR	self-assessment report	WHFF-CH	Wald- und Holzforschungsförderung Schweiz
SCNAT	Swiss Academy of Sciences	WHO	World Health Organization
SDC	Swiss Agency for Development and Cooperation	WMO	World Meteorological Organization
SDSC	Swiss Data Science Center	WoS CC	Web of Science Core Collection
SERI	Swiss State Secretariat for Education, Research and Innovation	WSL	Swiss Federal Institute for Forest, Snow and Landscape Research
SFOE	Swiss Federal Office of Energy		

