



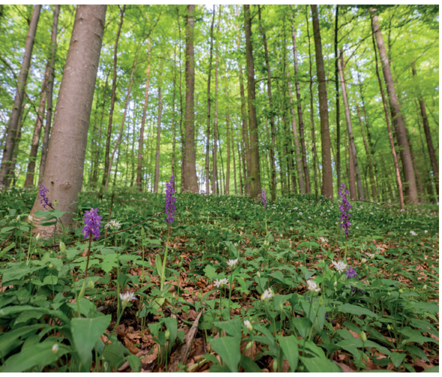


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Towards an Advanced Inventorying and Monitoring System for the Swiss Forest

Editors

Marco Ferretti, Christoph Fischer, Arthur Gessler

Swiss Federal Institute for Forest, Snow
and Landscape Research WSL
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Abstract

Switzerland has a long tradition in monitoring forest resources, and today Swiss forests are being monitored by several monitoring programmes. Although the original grid of the Swiss National Forest Inventory served as the basis also for other programmes (e.g. Sanasilva, Biodiversity Monitoring Programme), they are now installed on different sub-grids with only partial overlap, have different frequencies of data collection and different visitation timing within the year. This situation can cause important signals to be missed or not properly quantified.

Swiss AIM is an initiative with the goal to make the existing Swiss forest inventorying and monitoring infrastructures more dynamic, suitable and responsive with respect to current and predicted environmental challenges. Building upon the existing large-scale monitoring networks (e.g. Swiss National Forest Inventory – NFI, Long-term Forest Ecosystem Research – LWF), Swiss AIM will offer a cooperative conceptual and operational framework to support integrated data collection, evaluation, interpretation, analysis and modelling in space and time. The initiative will also support timely reporting about the forest condition in Switzerland.

In this volume, we present the main inputs and outputs of the internal WSL Workshop “Towards an Advanced Inventorying and Monitoring System for the Swiss forest”, held virtually on 12 November 2020. Participants at the Swiss AIM Workshop were asked to express their view on the Swiss AIM initiative from several perspectives. They presented scientific questions for a variety of temporal, spatial, environmental and ecological scales: from single sites to the entire country, and from cells to ecosystems. Comprehensive lists of possible measurements and sampling types that build upon the existing ones were also presented. There was a clearly expressed willingness to support the initiative, mainly by providing expertise and organisational support.

This report is structured into three parts, i.e. two main parts and an Annex. Part 1 describes the overarching vision of Swiss AIM and summarizes the ideas and main inputs emerging from the virtual Swiss AIM workshop. Part 2 covers the expression of interest, scientific questions, data requirements and possible contributions from individual Research Units, Programs and Centers.

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Part 1. Swiss AIM: vision, ideas and main inputs emerging from the Swiss AIM workshop

1. Origin, features, vision and objectives of the Swiss AIM initiative

Marco Ferretti
Forest Resources and Management, Swiss Federal Research Institute WSL

Abstract. *Swiss AIM is an initiative with the goal to make the existing Swiss forest inventorying and monitoring infrastructures more suitable and responsive with respect to current and predicted environmental challenges. Building upon the existing large-scale monitoring networks (e.g. Swiss National Forest Inventory – NFI, Long-term Forest Ecosystem Research – LWF), Swiss AIM will offer a cooperative conceptual and operational framework to support integrated data collection, evaluation, interpretation, analysis and modelling in space and time. The initiative will also support timely reporting about the forest condition in Switzerland. In this report, the intended main characteristics of the initiative are outlined as they were presented at the Swiss AIM Workshop, an WSL internal event held virtually on 12 November 2020.*

Introduction

Switzerland has a long tradition in monitoring forest resources, with the growth and yield research on permanent plots started in 1885 (https://www.wsl.ch/en/forest/forest-development-and-monitoring/growth-and-yield.html ; Forrester, 2021). Today there are many monitoring programmes covering Swiss forests (Rigling et al., 2015), with the Swiss National Forest Inventory (NFI) (e.g. Fischer and Traub, 2019), the Sanasilva Inventory (e.g., Schwyzer et al., 2015), and the Biodiversity Monitoring programme (e.g. Hintermann et al., 2000) being some of the most important large-scale national networks. These three programmes are exemplary in that they have important connections and differences. They are connected from the point of view of their design: they are all based on the NFI 1 × 1 km systematic sampling grid developed for the first NFI (NFI1) (EAFV, 1988; Fischer and Traub, 2019) that took place between 1982 and 1986 with an intended inventory cycle of 10 years. The Sanasilva programme started in 1985 on a 4 × 4 km subgrid of the NFI1 and with an annual frequency. Later on, however, all three programmes underwent substantial changes: since the second NFI in 1993–1995 (Brassel and Brändli, 1999) the NFI has been based on a different subgrid (approx. 1.41 × 1.41 km), and since 2009 it has adopted the form of a continuous forest inventory, with nine annual panels of plots visited over a 9-year inventory period (Lanz et al., 2019). The sampling intensity of Sanasilva was also relaxed over time, first to 8 × 8 km and – in 1998 – to 16 × 16 km (with alternated intensity between 1993 and 1998). Since 2001, another subgrid (4 × 4 km) of the original NFI1 1 × 1 km grid has been adopted by Biodiversity Monitoring Switzerland, with visits every 5 years for data collection. Alongside these three main programmes, from 1983 on a number of other surveys (e.g.

foliage sampling, soil sampling and deadwood surveys) have been carried out on NFI plots and subnetworks (e.g. Landolt et al., 1984).

In summary, while the original NFI1 1 × 1 km grid served as the basis for the three main programmes, they are now installed on different subgrids with only partial overlap (Figure 1) and have different frequencies of data collection (1, 5 and 9 years). They also differ in terms of visitation timing within the year: for example, visits to NFI plots typically take place between April and October, while they happen in July to August in the Sanasilva programme. Although this situation is based on consolidated methodologies and logistic requirements, it may have a considerable impact on the results of the inventories. For example, with their original frequency neither NFI nor Sanasilva were able to detect or quantify the impact of the 2018 megadrought on forest health and productivity. A special survey carried out on some NFI plots, integrating NFI and Sanasilva methods, was needed to quantify these effects, and it demonstrated the need for a more responsive monitoring system (Rohner et al., 2021), a concern emphasised also by Schuldt et al. (2020). Since climate change will likely result in changes in the frequency and dimension of disturbances like extreme weather and pests (e.g. Jakobi et al., 2018), the ability of a monitoring system to react rapidly and possible on an ample basis of attributes will become increasingly important. Then the question arises as to whether the solid foundation provided in Switzerland by the various forest inventorying and monitoring programmes is actually sensitive enough to handle the new challenges our forests are currently, and will continue to be, confronted with. In operational terms: how can we make our forest inventorying and monitoring more dynamic and sensitive?

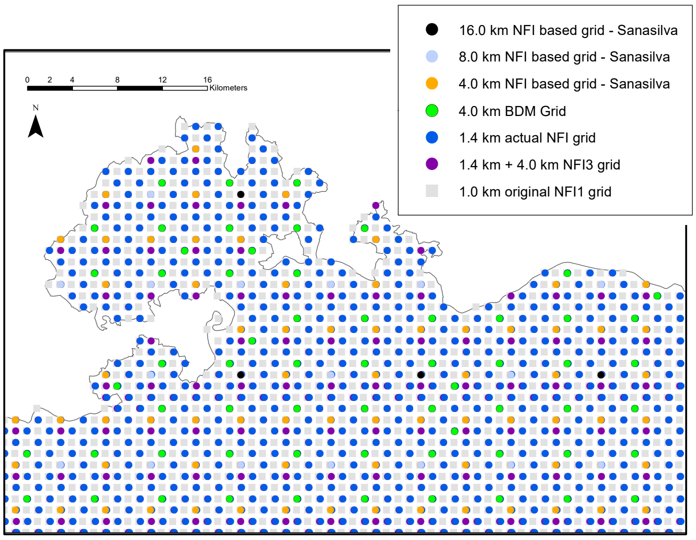

Figure 1. Example of the different inventory and monitoring grids stemming from the original NFI1 1 × 1 km grid in North-Eastern Switzerland, mostly in the cantons of Schaffhausen, Thurgau and Zürich. Courtesy: C. Fischer.

In this report the Authors summarise the main results of the WSL Internal Workshop held virtually on 12 November 2020. In this Chapter 1 I present the main characteristics of Swiss AIM, as envisioned within the WSL Research Unit (RU) Forest Resources and Management (FOREMA). In Chapter 2 we summarise the input received from the various RUs during the Workshop, providing detailed information on the input in Part 2. In Chapter 3 we present the main issues that have emerged and provide a possible roadmap for the initiative.

Swiss AIM: what is it, and why is it important?

Origin and vision

Based on the concerns and evidence described above, the Swiss Advanced Inventorying and Monitoring (Swiss AIM) initiative was first proposed as part of the 2021–2024 strategy of the Research Unit (RU) Forest Resources and Management. It was conceived in consultation with the Swiss National Forest Inventory (NFI) and several RUs at WSL. In its feedback, the WSL Directorate explicitly welcomed the initiative and stated that it was “very relevant for the forthcoming WSL initiative Extremes”.

The starting vision for Swiss AIM, as developed within the RU FOREMA, reads as follows:

“*An integrated terrestrial and remote sensing observation system based on a permanent panel of enhanced NFI plots. It will provide high-quality periodical (infra-annual, annual, multi-annual) results with known statistical errors for the status, change and response of forests to biotic and abiotic drivers*”.

There are several features inherent to such a vision. Swiss AIM:

(i) is intended as a cooperative effort. Scientists and experts from different WSL RUs will join forces to enable a comprehensive assessment and monitoring of the condition of the Swiss forest. External partners and/or stakeholders (e.g. BAFU) will play a central role, which will be evaluated in the design phase of the initiative.

(ii) will involve the design, testing and implementation of an inventorying and monitoring system based on an annual, permanent panel of enhanced NFI plots. It will offer the basis for national-scale, annual data and estimates of the status of and change in key attributes linked to forest responses to biotic and abiotic drivers, including extremes.

(iii) has the ambition to be exemplary at the national and international level. Its vision, structure and inherent cooperation will permit results and outputs of unmatched quality. It will be inspired by, and will inspire, development in the field of forest inventorying and monitoring within and beyond Switzerland.

(iv) will serve science, practice and society at large. Swiss AIM will open research opportunities and will permit timely and closer monitoring of the Swiss forest from a broad range of scientific perspectives. This could lead to faster identification and reporting of possible problems and prompt science-based measures to protect and enhance the Swiss forest.

Key conceptual implementation issues

The following issues need to be considered when designing and implementing Swiss AIM:

(i) It is necessary to achieve a shared definition of all individual terms key to the design process. For example, the “permanent panel of plots” (the designated set of NFI plots to be visited annually) and what will be the “enhanced NFI plots” (plots with a special design to permit frequent visits and destructive sampling) need shared and unambiguous definitions. Common terms, such as error, visit, quality, attribute, driver and data management, also require shared definitions.

(ii) A sound statistical perspective is essential for the short- and long-term success of the initiative. Ideally, it will be implemented according to a shared design that supports estimations of status and changes.

(iii) It has to adopt a multi-media perspective. It will make use of terrestrial, close-range and remote sensing observation techniques, and will consider aspects beyond the tree components of forest ecosystems.

(iv) It should integrate the spatial allocation and time frequency of measurements. This will be attribute specific and designed to permit effective detection of status and changes. For attributes potentially subject to changes over the vegetative season (e.g. some tree canopy and vegetation attributes), repeated measurements within the year need to be considered.

(v) It should enable “dialogue” between data types. As the NFI will be the backbone of the entire initiative, new data will need to be compatible with NFI standards. This does not mean it will be stored in the NFI database: federated databases, each under the responsibility of the organisational unit in charge of the relevant survey/investigation, represent the most feasible and convenient option.

(vi) It should be designed to enable a denser frequency of reporting to catch the pulse of the Swiss forest. The frequency should be tailored to the needs of possible stakeholders and based on the time resolution of the various surveys contributing to Swiss AIM.

Expected Benefits

Despite several challenges anticipated for the design and implementation stages, Swiss AIM is expected to help bring about considerable advances. They fall into three main categories:

(i) Enhanced scientific performance. Swiss AIM will support:

- improved coordination between scientists / initiatives;
- a higher level of integration through a consistent framework for data collection across groups / programmes;
- enhanced responsiveness to sudden events (e.g. drought, storm, temperature extremes); and
- an expanded capability for detecting, understanding and predicting change; for example, with its annual resolution, Swiss AIM has the potential to enhance the interpretation of changes detected between two subsequent NFI cycles.

(ii) Enhanced reporting on the condition of the Swiss forest and its response to disturbances; for example, inventorying and monitoring activity organised on an annual/subannual basis will be considered the necessary precondition for annual reporting.

(iii) Enhanced institutional performance through (further) strengthening of the WSL position in the field of inventorying and monitoring.

Altogether, the above benefits will result in an augmented ability of Switzerland to respond to the challenges posed by global change, and will further promote Swiss forest science.

Timelines

Three phases can be provisionally envisioned:

- *Preliminary phase*, dedicated to preliminary discussion within and between Research Units / Programmes / Centres at WSL. This took place in 2020 and culminated with this report about the Internal Workshop and consultation within WSL (see below).

- *Design and explorative-testing phase*, dedicated to the development of the design and exploration of its applicability in the field. It is planned as an iterative process occurring between January 2021 and December 2022.

- *Implementation phase*, dedicated to making the system operational. Ideally, it will start in January 2023.

Governance and resources

Initially a strategic initiative originated from the RU FOREMA, Swiss AIM will develop beyond the organisational dimension of the RU. How and in which form this can be achieved and whether an intermediate step (e.g. as a project) will be necessary is still a matter of discussion and will be clarified in the design phase. Swiss AIM will need resources for its exploration and design, implementation, and maintenance. The size and possible source of these resources are currently being explored.

The Swiss AIM Workshop

A Workshop "…with all interested RUs to discuss the scientific questions … and to prepare an adequate selection of NFI plots" was explicitly requested by the WSL Directorate when giving its feedback on the proposed Swiss AIM strategic initiative from the RU FOREMA. The Internal Swiss AIM Workshop was then organised and held virtually on 12 November 2020: it was the final step of the preliminary phase and the first step of the WSL internal consultation and design process. The Workshop was designed to explore scientific questions and information needs from a broad range of potentially interested RUs, programmes and initiatives at WSL. The Workshop was intended for internal WSL potential partners only – an external audience will be targeted at a later stage. Heads of interested RUs at WSL or designated delegates / Programme leaders / leaders of Initiatives and Centres were invited. Participants are listed in Part 3.

The Workshop objectives were defined as follows:

- present the background and vision of the Swiss AIM initiative;
- identify key scientific questions from WSL Research Units / Programmes / Centres;
- document demands / expectations for data collection (e.g. nature, type and frequency of observation, need for destructive sampling) to address key questions;
- identify challenges in terms of design, opportunities, needs and constraints; and
- Identify the next operational steps.

Participants were asked to provide answers to the following questions (see Part 2 for details):

- Position of the RU / Programme / Centre with respect to Swiss AIM and its starting vision (see above); e.g. "Am I interested, and why?"
- Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs); e.g. "What do I want / need to investigate, now and in the future?"

- Scale of interest and/or statistical inference, e.g. from the total forest to individual tree species, from the entire country to individual cantons, and combinations; e.g. “What scale do I want my results to be applicable to? (site, canton, region, Switzerland)”
- Statistical requirements (if any) in terms of the precision of status and change estimates, if any; e.g.: “What level of uncertainty am I willing to accept? What amount of change would I like to detect? What level of confidence do I require?”
- Related data needs: attributes to be measured, plots, trees, destructive sampling, instruments; e.g. “What would I like to observe / measure / collect? At what intensity and how frequently? What is my prioritised ‘wish list’?”
- Support and resource availability; e.g. “How can I support Swiss AIM? Do I have resources to invest in the initiative? Or do I need additional resources?”

Summing up

Swiss AIM has been proposed to build upon the strong basis offered by the existing forest inventorying and monitoring infrastructure in Switzerland, and to make it more responsive with respect to current and predicted biotic/abiotic stressors that will challenge the Swiss forest. The intention of Swiss AIM is to offer a conceptual and operational framework to support integrated data collection, evaluation, analyses, interpretation, modelling, and reporting.

In synthesis, Swiss AIM is intended to be a co-operative effort to concentrate on a statistically representative set of plots from a number of surveys covering a wide range of attributes in relation to key environmental and forest-relevant themes, and considering different time resolution needs. The Swiss AIM Workshop was the first opportunity to share the experience, expertise and expectations of many interested scientists and organisational entities at WSL (see Parts 2 and 3).

Acknowledgements
I am grateful to all Workshop participants for their input. Christoph Hegg provided useful feedback on the Workshop’s structure and organisation. Along with other participants from the NFI programme (see Chapter 5), Andri Baltensweiler, Fabrizio Cioldi, Brigitte Rohner and Jürgen Zell provided useful comments and input during earlier discussion rounds within the RU FOREMA.

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2. Swiss AIM in the perspective of WSL Research Units, Programmes and Centres

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(3) Forest Dynamics, Long-term Forest Ecosystem Research (LWF), Swiss Federal Research Institute WSL

Abstract. *Participants at the Swiss AIM Workshop were asked to express their view on the Swiss AIM initiative from several perspectives. They declared to be interested in the Swiss AIM initiative and suggested a series of scientific questions for a variety of temporal, spatial, environmental and ecological scales: from single sites to the entire country, and from cells to ecosystems. Comprehensive lists of possible measurements and sampling types that build upon the existing ones were also presented. Some of them may be demanding in conceptual and operational respects. There was a clearly expressed willingness to support the initiative, mainly by providing expertise and organisational support.*

Introduction

In Chapter 1 we introduced the overall vision for the Advanced Inventorying and Monitoring System for the Swiss Forest (Swiss AIM) and presented the background of the WSL Internal Workshop. Here, we summarise the input received from the various presentations (see Part 2 and https://www.wsl.ch/de/wald/waldentwicklung-und-monitoring/swiss-aim-an-advanced-inventorying-and-monitoring-system-for-the-swiss-forests.html) and participants (see Part 3). Detailed responses from individual Research Units/Programmes/Centres are provided in Part 2.

This Chapter follows the same structure adopted for the presentations given during the Workshop: scientific questions, scale of interest, statistical requirements, data needs, possible support. This facilitates the presentation of the different interests, perspectives and expectations of the various RUs, Programmes and Centres at WSL.

A preliminary question posed by the Workshop organisers was about the interest of the delegates with respect to the Swiss AIM initiative. It is worth mentioning that all the participating RUs, Programmes and Centres declared explicit interest here. The most frequently reported reasons were the potential to obtain a unique measurement network and dataset that can serve to answer a multitude of scientific questions in an integrative manner (see e.g. Part 2). The fostering of synergies among existing programmes, the potential to integrate short- medium- and long-term events/responses, and a greater chance of detecting, understanding, modelling and predicting changes and effects of disturbances were largely acknowledged as the most important drivers of interest.

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs)

Scientific questions presented at the workshop have in general both a research and applicative character and can be categorised into three groups (Table 1 – see Part 2 for details).

Questions related to the assessment of the Swiss forest's status and changes.

This category includes the most typical set of questions for inventorying and monitoring programmes. Here, the focus is on obtaining representative data to permit unambiguous statements on the condition (status) and development (change, trends) of selected attributes over the target statistical population at a defined time resolution and in relation to biotic and abiotic drivers, including extremes. Typical attributes mentioned here include those referring to forest health, growth, regeneration and diversity, and those connected to related ecosystem services (e.g. climate protection, protection against avalanches and rockfall, leisure).

Questions related to understanding processes and dynamics.

Effects of climate change and interactions with other abiotic and biotic stressors on several processes and dynamics and on the functioning of forest ecosystems were the main concern of the scientific questions reported under this category. This is especially true in consideration of the foreseen acceleration of several processes exacerbated by climate change. There is, however, a clear indication to go beyond trees, and to consider an enlarged set of ecosystem components and trophic levels. Further, the way in which management can impact forest response to stressors, forest biodiversity, and the way the forest is considered for recreational purposes were frequently mentioned in the scientific questions presented.

Questions related to the enhancement of the monitoring and inventorying techniques.

Supplementing and complementing the existing data catalogue available for the (possible subset of) NFI plots, expanding the focus towards a response-oriented inventorying and monitoring scheme by enhancing the time frequency of observation and data integration, and improving the link with close-range and non-close-range remote sensing techniques were the subjects of the scientific questions reported under this category.

Table 1. Main categories of scientific questions presented at the Swiss AIM Workshop. See Part 2 for details.

Status and changes	**Understanding processes and dynamics**	**Enhancement of monitoring and inventorying techniques**
Obtain time-integrated representative data / information on the status of and changes to key attributes related to growth, health, diversity and performance, in terms of climate protection, adaptation/acclimation and use of the Swiss forest.	Understand the effects of drought- and climate-change-induced acceleration on several ecosystem processes (e.g. health, mortality, nutrients, carbon cycle, water availability).	Enlarge data portfolio, augment time frequency, and enhance data connection, integration and use on a possible set of NFI plots.
Assess long-term trends in tree/ecosystem responses, functioning and regeneration in relation to defined biotic and abiotic stressors and their interactions.	Understand how biotic and abiotic variables affect forest biodiversity and functional traits.	Explore and create linkages from close-range and non-close-range remote sensing data to in situ measurements on trees/vegetation/soil/microclimate for upscaling in situ measurements.
Assess current and lagged effects of extreme drivers and their combination on growth, health, mortality, regeneration and diversity.	Understand genomic adaptation of forest trees and the functional reaction of mycorrhiza to environmental change, such as climate change and drought.	Include genomic and metagenomic techniques in monitoring schemes.
	Understand the relationship between different types of forest management, forest biodiversity at all levels and forest structure.	
	Understand the development of biodiversity in common and special forests (e.g. forest reserves).	
	Identify factors driving recreational preferences and understand how forest management may influence them.	

Scales of interest and/or statistical inference

This question was originally suggested with the intention to explore the intended domain of interest for the different Research Units, Programmes and Centres, e.g. “What scale do I want my results to be applicable to? (site, canton, region, Switzerland)”

Temporal, spatial, environmental, administrative and ecological scales were all mentioned in the Workshop as scales of interest for inference – not only in a statistical sense (Table 2, details in Part 2).

Table 2. Different scales at which the need for some kind of statistical or circumstantial inference was reported at the Swiss AIM Workshop. The order of each list reflects the frequency of mentions. Asterisks identify the most frequently mentioned scales. See Part 2 for details.

Temporal scale	**Spatial and environmental scales**	**Ecological scale**
Short term (<1 yrs) Short and medium term (1–10 yrs)*	Entire country *	Trees and higher plants * from cell to population
Long term >10 yrs	Biogeographic region	Other groups of organisms
Both short and long term*	Environmental gradients	Soil
	Individual site/plot	Entire ecosystem
	Canton	
	Economic region	
	Unusual/ rare / iconic forests and trees	
	Forest enterprise	

In general, the applicability of conclusions / inference to trees for the entire country and for both medium- and long-term time horizons were the most frequently mentioned ecological, administrative and temporal scales. The possibility to infer at the level of biogeographic region and along environmental gradients was also mentioned and was the subject of a lively debate during the Workshop (see Part 2).

Statistical requirements (if any) in terms of the precision of status and change estimates

Although most of the participants emphasised the importance of high and explicit targets for the precision of estimates of status and change (see Part 2), very few provided concrete suggestions. In many cases, the definition of such a target was considered not possible yet, as it may be substantially different for individual attributes. An additional, related concern that was raised is data quality: many field measurements are known to be prone to some considerable measurement error that can have a substantial impact on status and change estimations.

Related data needs: attributes to be measured, plots, trees, destructive sampling, instruments

Given the diversity of background, expertise, expectations and ecological targets involved, the emerging wish list for measurements to be undertaken in the newly designed set of plots for Swiss AIM is very long and diverse. Table 3 includes a summary of the main categories of attributes that were mentioned at the Swiss AIM Workshop. Details can be found in Part 2.

While measuring at least some “traditional” attributes on the NFI and LWF / Sanasilva plots is a must for comparison purposes, three aspects emerge:

- including vascular plants and other organismal groups (e.g. birds, ants) to better evaluate biodiversity;
- carrying out some destructive/invasive sampling, in particular tree coring, to better evaluate (tree growth) responses to past disturbances and extremes; and
- adding some on-site recording of environmental variables.

Whether these additions will actually be possible, considering the need to protect NFI plots from bias related to visitation and monitoring activity, will be clarified during the design process.

Possible support and resource availability

Different possible contributions were mentioned by the participants (see Part 2). They include (in descending order):

- provision of expertise (specific technical knowledge, methods, models);

- provision of existing data, and availability to carry out data collection (partly with own resources; partly with third party money); and
- support in communication and networking activity (e.g. workshops).

A clear need for additional resources emerged from the various contributions and from the discussion.

Table 3. Data needs mentioned at the Swiss AIM Workshop in relation to the foreseen data sources. See Part 2 for details.

Compartment	**Data need mentioned**	**Data source identified**	**Destructive / invasive sampling**
Atmosphere / environment	Nutrients, ozone, other environmental characteristics collected on site	Terrestrial / models	Yes / No
Area/plot	NFI / LWF / Sanasilva catalogue plus additional site characteristics (e.g. LAI, roughness of terrain)	Terrestrial and remote	No
Trees	NFI / LWF / Sanasilva catalogue	Terrestrial and remote	No
Trees	NFI / LWF / Sanasilva catalogue plus additional attributes / damage symptoms and agents or causes	Terrestrial and remote	No (in general). Potentially yes for lab identification
Trees	Tree-rings, genetic analyses	Terrestrial	Yes
Vascular plants	Diversity	Terrestrial	No
Other organismal groups	Diversity	Terrestrial	Potentially yes
Soil	Nutrient availability, carbon sequestration and soil biota, organic biomass pool, physical characteristics	Terrestrial	Yes

Conclusions

Participants clearly expressed their interest in the Swiss AIM initiative and suggested a series of scientific questions concerning a variety of temporal, spatial, environmental and ecological scales: from single sites to the entire country, and from cells to ecosystems. Comprehensive lists of possible measurements and sampling types that build upon the existing ones were also presented, some of which may be demanding in conceptual and operational terms. Finally, there was a clearly expressed willingness to support the initiative, mainly by providing expertise and organisational support. At the same time, the need for additional resources was expressed by many contributors.

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3. Swiss AIM: conclusions from the Workshop and next steps

Marco Ferretti (1), Christoph Fischer (2), Arthur Gessler (3)

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Abstract. *Six main messages emerged from the Workshop. They include: (i) expression of ample interest and support; (ii) consideration of a broad range of scientific questions; (iii) interest in promoting cross-scale research; (iv) the wish to couple visual observations, environmental specimens, automated measurements, and existing data resources; (v) the need for a robust design; and (vi) the need for additional resources. The design, access to resources and governance will be addressed in 2021 and 2022. Swiss AIM is an ambitious initiative. For its success, it is necessary to resist the temptation to do everything for everybody all at once: it will probably be best to start with a set of feasible solutions to test the Swiss AIM concept, which can then be expanded in subsequent stages.*

Introduction

In Chapter 1 we introduced the Swiss AIM initiative, its origin, motivation and vision. In Chapter 2 we synthesised the input received from the Workshop participants (see Part 2 for details) and attempted to extract the main issues that emerged. Here, we go a step further and attempt to identify the main messages that we consider relevant for the development of the initiative. We extracted them from the above-mentioned input and put them in a form that facilitates the identification of potential issues for consideration and next steps.

Six messages

We identified six messages emerging from the Workshop:

Message 1: There is ample interest in Swiss AIM and widespread willingness to support it.

Participants from WSL Research Units, Programmes and Centres that attended the Workshop all declared an interest in Swiss AIM. The main drivers of interest were reported to be the potential for highly integrative studies with a sound statistical basis that can be initiated by concentrating several investigations on (a possible selection of) NFI plots. This is considered useful to improve the understanding of the dynamics of the Swiss forest, and to enhance the scientific performance of WSL.

This general interest is reflected in the expressed willingness to concretely support the initiative, mostly with expertise, organisation and data. In a few cases, the possibility to contribute to data collection using one's own budget was mentioned.

We acknowledge the expressed interest in contributing and supporting Swiss AIM: this is an important pre-condition for the entire initiative.

Message 2: Swiss AIM will support assessment, detection, understanding and prediction, thus helping to advance science.

Several scientific questions were presented at the Workshop. Some of them were about status and change, and were therefore related to estimation and assessment. Some others were concerned with the detection of the effect of different biotic and abiotic stressors, and therefore with the understanding of ecosystem processes and dynamics, which is pivotal for predictions. A final group of questions was related to the improvement of monitoring and inventorying techniques, including both terrestrial and remote sensing methods.

We welcome such a diverse set of questions. Developing a conceptual and operational framework to incorporate and prioritise the reported scientific concerns and questions will be a challenging, important part of the design process.

Message 3: Swiss AIM should promote/encourage cross-scale research.

There was a general interest in covering diverse spatial, temporal, environmental and ecological scales (see Chapter 2). The status of and changes to the tree component in both the short and long term are still largely the focus of most scientific questions, especially in relation to drought and climate change. However, several other organismal groups (e.g. birds, ants) and ecosystem compartments (e.g. atmosphere, soil) for which Swiss AIM could provide a robust conceptual and operational framework were mentioned.

Along the same lines, together with the national scale, other administrative (from cantons to enterprises) and environmental (e.g. temperature and nitrogen deposition gradients) scales were mentioned.

It is very unlikely that Swiss AIM will be able to cover all possible scales at all levels with acceptable statistical confidence. The decision about the targeted spatial, temporal and ecological scale will be an important step in the design process that will go hand-in-hand with the prioritisation of scientific questions.

Message 4: Visual observations will ideally be supplemented by the collection of environmental samples and automated measurements.

The need to collect specimens (e.g. soil, tree cores) and install measurement devices (e.g. meteorological sensors) in or near the NFI plot and/or interpretation area was mentioned several times during the workshop. This is understandable as they may provide valuable additional data and information to better interpret non-destructive measurements, as well as the current and future development of the Swiss forest.

It has been pointed out that destructive sampling and devices may collide with the fundamental need to protect NFI plots from disturbances related to monitoring and from visible installations that can introduce unwanted bias. This issue will have to be considered carefully in the design process, and what can actually be done and where (e.g. NFI plot, interpretation area, elsewhere) must be clearly defined.

Message 5: A robust statistical design is needed.

The message did not emerge clearly or univocally, but the need to rely on a robust statistical design was acknowledged by attendees from most of the participating RUs / Programmes / Centres. Here, the Swiss NFI – with its systematic sampling design and standardised plot design – offers a solid basis to build upon. On this basis, the total number of plots necessary to achieve an acceptable statistical precision of estimates for population parameters in relation to the status of and changes to key attributes will need to be defined, also taking into account the actual feasibility. Along the same lines, an enhanced plot design should be explored to accommodate measurements traditionally not carried out by the NFI and the collection of samples (if possible) (see Message 4). The sampling design (plot network) and plot design of Swiss AIM will clearly represent a challenging step for the initiative.

Message 6: Additional resources are needed.

Together with the interest and support reported above, there was a large consensus that an initiative like Swiss AIM will need additional resources. The amount of resources will be clarified during the design process, when e.g. the number of plots and the necessary measurement effort, data management and reporting will be defined. Potential access to resources needs to be identified and explored, both in-house and on a third-party basis.

Provisional roadmap and governance

The provisional roadmap includes the three main phases reported in Chapter 1 (Figure 1):

- *Preliminary phase*, dedicated to preliminary discussion within and between Research Units / Programmes / Centres at WSL.

- *Design and explorative-testing phase*, dedicated to developing the design and exploring its applicability in the field. It is planned as an iterative process occurring between January 2021 and December 2022, and will involve external partners (e.g. BAFU). It will include a second Workshop to discuss first design proposals, first field test-runs on selected test plots, design adjustments, larger testing and final adjustments. It will culminate with a third Workshop, where the final design will be presented.
- *Implementation phase*, dedicated to making the system operational. Ideally, it will start in January 2023.

Such a roadmap is provisional and will be adapted according to the results of the design and further consultation process within and outside WSL, the latter starting with this report.

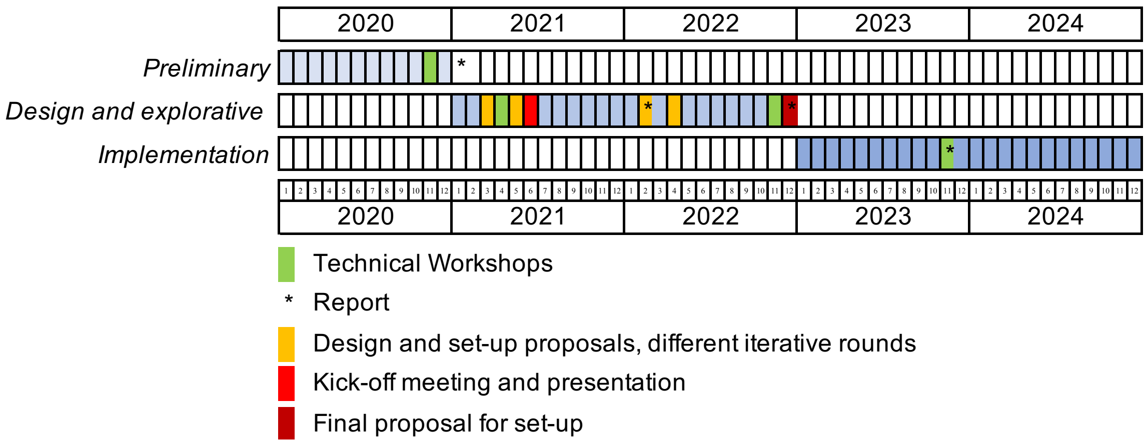


Figure 1. Provisional roadmap as presented at the Swiss AIM Workshop. This roadmap will be adapted according to the results of the design and further consultation process.

Swiss AIM will build upon existing inventorying and monitoring programmes (e.g. NFI, LWF) that have their own governance. There are ongoing discussions at WSL about what kind of formal position and governance Swiss AIM will have, also considering the possible future development of the initiative. It is likely that an ad-hoc steering committee will be necessary, including non-WSL delegates as well. For practical reasons, at the first Workshop the three Authors of this Chapter were appointed as the “starting group” for such a committee, with the addition of further members foreseen for spring 2021 and the end of 2022, when the final set-up is expected to be defined.

Conclusions

The Workshop provided the forum for a productive exchange on how to enhance the high-quality forest inventorying and monitoring systems already existing in Switzerland, and develop it in a possible highly integrated manner: lots of input to ponder, many challenging yet intriguing and stimulating perspectives, and a great deal of work ahead.

Swiss AIM is an ambitious initiative that we hope will be exemplary at the Swiss and international level. For this reason, it is necessary to resist the temptation to do everything for everybody at once: it will be necessary to prioritise questions and objectives, develop a sound design and proceed step by step, maybe starting with a limited set of feasible solutions to test the Swiss AIM concept and expanding in subsequent stages.

Acknowledgements

We are grateful to all the participants at the Swiss AIM Workshop and to all those who contributed to input from WSL Research Units, Programmes and Centres.

Part 2. Position, scientific questions, data requirements and contribution from individual Research Units, Programs and Centers

4 Research Unit Forest Resources and Management

Marco Ferretti, Peter Brang, Christoph Fischer, David Forrester, Martin Hägeli, Janine Schweier, Esther Thürig

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

The Research Unit FOREMA is obviously interested as it is the promoter of the initiative. See Chapter 1 for details about the proposed vision and characteristics of the initiative.

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

FOREMA's scientific questions of interest concern the status of and changes to forest conditions and drivers of change. They are relevant in the short (s), medium (m) and long term (l).

Regarding the status of and changes to forest conditions:

- Obtain intra-annual (see below), annual and multi-annual quantitative estimates of condition and change in condition of the Swiss forest in relation to selected attributes of health (s–l. incl. mortality), growth (s–l), diversity (m–l), and regeneration (m–l). These are linked to important questions on the carbon cycle, sustainability, resistance and resilience of the Swiss forest.

Regarding the drivers of forest conditions. Role exerted by possible drivers, namely:

- Site and stand properties, and their change.
- Climate-related drivers, including wind and wet snow.
- Other air-borne drivers (nitrogen deposition, ozone).
- Silvicultural management.
- Biotic drivers (e.g. pests, pathogens, ungulates).
- Interactions among drivers.

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

Spatial: priority ("must"): entire Switzerland. If feasible ("nice-to-have") and in descending order: economic regions, cantons.

Temporal: priority ("must"): an annual resolution to estimate status and changes at a higher frequency. Within-year change to detect a seasonal signal will be also very important, as demonstrated by the 2018 megadrought (Rohner et al., Ecological Indicators, 2021, https://doi.org/10.1016/j.ecolind.2020.106903). With proper organisation and cooperation among different Research Units and Programmes, within-year changes can be obtained without additional measurement effort. To this end, the panel of plots to be visited annually could be divided into separate random sets (two or three), with each set visited in different time windows (see Figure 1). Differences in e.g. health condition between these sets can then be tested statistically. Also, cooperation between Research Units and Programmes can favour this solution.

Ecological: mostly the aboveground component and most important tree species/forest types (connected to space). However, the soil component (physical and chemical properties) is also important for growth models, and we are interested in the activities and suggestions coming from other RUs.

Environmental: most important gradients (e.g. of drought exposure; temperature, nitrogen deposition) that can be covered within the framework of the statistical design. They can be considered ad-hoc thematic panels embedded in the network. Consequences in terms of design-related issues and in potentially missing possible important gradients need to explored.

Statistical requirements (if any) in terms of precision of status and change estimates.

This must be defined for each estimate (total; mean) and in relation to minimum detectable change. In general, standard errors for population parameters (mean, totals) should be <5% at a 95% probability level.

SP	ES	LS	SP	ES	LS	SP	ES	LS
LS	SP	ES	LS	SP	ES	LS	SP	ES
ES	LS	SP	ES	LS	SP	ES	LS	SP
SP	ES	LS	SP	ES	LS	SP	ES	LS
LS	SP	ES	LS	SP	ES	LS	SP	ES
ES	LS	SP	ES	LS	SP	ES	LS	SP
SP	ES	LS	SP	ES	LS	SP	ES	LS
LS	SP	ES	LS	SP	ES	LS	SP	ES
ES	LS	SP	ES	LS	SP	ES	LS	SP

Figure 1. Possible scheme for differentiated the timing of visits to plots over a theoretical domain. Here three sets/timings (spring, early and late summer) are considered, but this setting can vary according to the topic under investigation and/or theoretical and practical considerations.

SP: SPRING, e.g visit from May to June

EA: EARLY SUMMER, e.g. visit in June-July

LS: LATE SUMMER, e.g. visit in August-September

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

Data needs are as follows:

- (Selected) attributes from NFI catalogue. Selection to be carried out in close contact with the NFI Programme. The NFI attributes will then be supplemented/complemented by:
- Forest health attributes from the ICP Forests (and Sanasilva) manual (https://www.icp-forests.org/pdf/manual/2016/ICP_Manual_2017_02_part04.pdf). This will ensure comparability also at the international level.
- Additional site/stand attributes (incl. those characterising management and ungulate populations) that can aid data interpretation.
- Local (plot, interpretation area) downscaled model estimates of key environmental variables: descriptors of past, current and future climate (incl. seasonal snow cover), nitrogen deposition, ozone, soil properties.
- Remotely sensed data on forest health and biomass.
- One-off collection of tree cores for tree-ring analyses, provided any influence on tree growth and vitality that may arise from coring is excluded. Location of tree coring (plots, interpretation area, …) needs to be designated to avoid unwanted effects and bias.

Support and resource availability.

Expertise available. Resources for design and implementation and coordination needed.

5 Swiss National Forest Inventory Programme

Martin Hägeli, Christoph Fischer, Meinrad Abegg, Berthold Traub, Esther Thürig.

Note: The Swiss National Forest Inventory (NFI) is a joint activity of the Federal Office for the Environment (FOEN) and the Swiss Federal Research Institute WSL. The FOEN has not been consulted yet. Additionally, there are no ongoing consultations or decisions at the project management or project committee level. Thus, the NFI cannot take a position, instead only expressing opinions.

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

To assess new variables and measuring methods, so far not assessed or implemented within the Swiss NFI, on plots using a systematic sampling grid.

- Chance to monitor short-term changes with annual re-measurements and to link them to NFI data to eventually provide an annual resolution of NFI data.
- Create synergies between existing monitoring activities at WSL, especially LFW/Sanasilva, but also including remote sensing.
- Enhance already existing cooperation between Research Units at WSL.
- Make use of existing technical and scientific knowledge at WSL.
- Extensive measurements on the Swiss AIM grid could be statistically combined with NFI data.

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

- The time frame can vary but probably long-term research questions will be our focus.
- Supply objective and representative information on the state of and changes in forests in Switzerland and its regions.
- Information about:
    - Forest Resources.
    - Sustainability in the Swiss forest.
    - Wood production.
    - Provision of climate protection services (GHGI).
    - Biodiversity.
    - Health and vitality.
    - Protective forest performance.
    - Adaptation to climate change.
    - Leisure and recreation in the forest (socio-economic FF).

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

- Spatial: Switzerland and its regions (depending on the sampling design, ecological and environmental regions are covered as well, depending on their size (self-stratification).
- Temporal: Less than five years, annual resolution if possible.

Statistical requirements (if any) in terms of precision of status and change estimates.

A sound sampling design has to be defined to allow for estimates of precision.

- Depending on the target variable, the required accuracy has to be defined. E.g. for growing stock an estimation accuracy of 1–2 % for the five production regions is required.
- In general terms, the precision of change estimations benefits from paired samples.

Thus, the application of pre-stratification designs / local subgrids should be avoided. These designs are subject to change by nature (changing interest in target variables and precision) and will lead to a reduction in the number of permanent samples in the sense of time series.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

No additional data needs were reported

Support and resource availability.

So far not discussed within the project committee (PAS) of the NFI. Any activity additional to the current NFI activities must be financed and approved.

- Statistical, methodological and organisational inventory knowledge support
- IT, data analysis and database support

6 Research Unit Forest Dynamics

Tom Wohlgemuth, Arthur Gessler, Marcus Schaub, Georg von Arx, Andreas Rigling.

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

Our interest is to detect and monitor effects of environmental change on forest growth, biomass accumulation, functioning, health and regeneration by:

- Assessing long-term trends in tree/ecosystem responses and functioning considering biotic and abiotic stressors.
- Validating tree/ecosystem modelling and remote sensing by means of ground truthing with measured data.
- Detecting potential signals from extreme events based on a subset of stratified samples (e.g. drought detection).
- Linking physiology with growth, vitality and mortality (combining classical monitoring with physiological remote sensing).
- Assessing regeneration in gaps; gap regeneration data returns different information than under-canopy regeneration on a subset (e.g. 4 × 4 km).
- Assessing plant species data in the understory every 10 years on a subset (e.g. 4 × 4 km).
- Assessing annual tree growth and biomass accumulation in response to environmental variability across forest ecosystems.

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

- *Climate change accelerates many processes in current forests*
    - How does acclimation, local adaptation and ecological memory affect trees' reactions to heat and drought.
    - How does drought interact with air pollution and nutrient inputs into ecosystems.
    - Develop early warning systems and large-scale risk assessment.
    - How fast does repeated drought affect tree composition: comparison of plots at low- and mid-elevation? Which tree species are affected mostly by re-occurring droughts?
    - How strongly does regeneration under the canopy differ from that in gaps regarding principal tree composition in samples? Which tree species differ mostly with stand tree composition in gap regeneration plots? Which species adapt to climate change best?
    - Which forest plant species shift along elevation gradients, and by how many metres per decade? Which site changes do shifting plant species indicate?
    - What is the carbon sequestration and wood production capacity provided by different species and forest ecosystems?

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

- Whole country, biogeographic regions (with different tree species) for:
    - Drought effects.
    - Regeneration in gaps vs. under canopy.
    - Plant species richness in the understorey.
    - From cells to ecosystems, from seconds to centuries.
- To be available and considered for European-scale risk assessments.
- To serve as flagship project across Europe.

Statistical requirements (if any) in terms of precision of status and change estimates.

- Drought effects: high precision with respect to species and elevation zones.
- Regeneration: high precision regarding biogeographic regions.
- Plant species richness: high precision regarding elevational zones nationwide.
- Environmental data: high-quality, fine-scale grid data or, even better, local data from NFI grid plots.
- Harmonised and geo-referenced data which can be used across several projects, approaches and scales.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

- Drought effects → annually, in sample subset.
    - Cleaned and gap-filled LWF data.
    - Dead branches (percentage per tree), crown transparency.
    - Nutrient input, ozone concentration.
    - Bark exudations.
    - Adaptation of traits measured in Wohlgemuth et al. (2020).
- Regeneration in gaps → decadal.
    - Gap assessment in 50 × 50 m interpretation area (example: Scherrer et al. in prep.).
- Plant species shifts (biodiversity) → decadal, on a subset (4 × 4 km).
    - Herbaceous species composition (continuation of Küchler et al. (2015).
- Growth / biomass & climate variability → annually.
    - Tree cores on subsets (1× per tree, thereafter with manual band dendrometers or measuring tapes).
- Physiological remote sensing: drone-based: campaign-wise → linked with satellite-derived information.

Support and resource availability.

- Support
    - Methodology.
    - Field work: to some extent by trainees.
    - Lab work: to some extent by trainees.
- Resources
    - Networks (SwissForestLab).
    - Established RI (Lötschental, Isotope lab, TreeNet, LWF, Pfynwald).
    - Experts in e.g. plant species, ecophysiology, dendrochronology, experimental long-term monitoring, ecosystem processes and mechanisms.
    - Great interest in working on joint proposals with NFI partners to acquire required resources.

7 Research Unit Forest Health and Biotic Interactions

Eckehard Brockerhoff and Valentin Queloz

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

The Research Unit Forest Health and Biotic Interactions is interested in the Swiss AIM initiative because forest health monitoring is an integral part of our work and there is much potential for increasing the usefulness of regular monitoring activities in Swiss Forests for our purposes.

In addition, we are interested in relationships between forest diversity and resistance/resilience against biotic disturbances (such as pests and pathogens) and abiotic disturbances (such as climatic extremes and wind storms).

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

Regarding forest health monitoring, our interests include:

- General forest health monitoring (for native pests and pathogens).
- Surveillance for invasive pests and pathogens.

Furthermore, we are interested in:

- Interactions between forest diversity and insect pests, pathogens and their impacts.
- Interactions between forest diversity and invasive species (presence and abundance).
- Interactions between forest diversity and abiotic disturbances.

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

The scales of interest to us range from the scale of the entirety of Switzerland or larger (including adjacent countries) down to specific forests or a subset of plots. In addition, our interests range from single trees and/or pest/pathogen species to entire communities.

Statistical requirements (if any) in terms of precision of status and change estimates.

Pests and pathogens often occur in patches and typically affect only certain tree species. That is why the LFI plots often miss the occurrence of pest and pathogen problems or they are detected only when large areas are affected. Especially for the purpose of surveillance of recent invasions of non-native pests and pathogens, more frequently assessed plots are of greater interest than the current LFI procedure. However, we appreciate that there are limits to what is realistic.

Also of interest is that the main tree species (and different age classes) are well represented in the monitored plots.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

In addition to generic descriptions of tree health (such as crown transparency and defoliation), we would be interested in more detailed descriptions of forest health concerns that allow better identification of the responsible agents (pest and pathogen species), which is currently only rarely possible.

Monitoring once per year is often sufficient, although some pests and pathogens can only be encountered or identified during certain times of the year. In this sense, site visits more than once per year would be preferable.

Sampling would not normally be destructive.

A standardised plot size would be ideal. For biodiversity studies, the current plot size is not optimal but should still be manageable.

Support and resource availability.

The Forest Health and Biotic Interactions Research Unit, and in particular the Swiss Forest Protection Group may be able to support the Swiss AIM initiative. For example, we may be able to obtain funding from the cantons or FOEN to allocate to surveillance. We may also be able to assist with the assessment of some parameters in the field, depending on the availability of suitable funding. There is a possibility that WSS staff may be able to do site visits, although not across all LFI plots.

8 Research Unit Forest Soil and Biogeochemistry

Ivano Brunner, Frank Hagedorn, Jörg Luster, Katrin Meusburger, Peter Waldner

Position of the RU / Programme / Centre / Initiative at WSL with respect to the Swiss AIM and its starting vision.

The RU is interested in Swiss AIM because:

- AIM is representative of the Swiss Forests.
- AIM can be linked to the pan-European ICP Forests Level I plot network (Sanasilva Inventory) that is representative of Europe's forests.
- AIM facilitates upscaling of findings from the Level I and Level II plots (LWF).
- AIM enables links between below- and above-ground surveys in a common network beyond LWF.
- The RU intends to repeat past selected sampling campaign(s) on NFI subgrids.

Key scientific questions: current and foreseen in the medium (5–10 yrs) and long term (>10–50 yrs).

- Nutrition: Is soil nutrient availability sustainable in Swiss forests? Is the tree nutritional status changing?
- Carbon cycle: How do soil carbon pools develop?
- Drought: Where and when do water availability constraints occur in Swiss forests (near-real-time assessments)? How do these constraints relate to above-ground observations (defoliation, die-back, infection with pathogens)?
- Soil functions: How do changes in soil functions and their interaction with other drivers impact forest services?
- Biodiversity: Which factors influence the soil biota, mycorrhiza and vegetation biodiversity, and vice versa?

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

Regarding the spatial scale, the RU is interested in an intermediate (e.g. 8 × 8 km) scale for sampling campaigns to investigate changes in soil condition and nutrition status, as well as an extended basis for water budget modelling.

The temporal scale of our interests ranges from season to annual for drought- and plant-growth-related aspects, and up to decades for soil-formation-related aspects.

Regarding a potential stratification of plots, the geology, soil type (e.g. WRB soil class), forest type, exposure, N deposition, and MAT and MAP parameters are most relevant for our RU.

Statistical requirements (if any) in terms of precision of status and change estimates.

Regarding nutrient and carbon cycles, the statistical requirements for AIM can be derived from the ICP Forests Manual (e.g. to detect changes in atmospheric deposition of nitrogen and sulfur deposition of more than ±30% within 10 years).

Regarding water budget modelling, the statistical requirements for the necessary measurements on AIM plots should be as such that drought stress categories can be assigned to individual months with a reasonably small uncertainty.

We envisage a significance level of 95% for the above-mentioned confidence intervals.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

The RU (S. Zimmermann) plans to repeat the Soil Inventory on an 8 × 8 km grid e.g. every 10–30 years, to gain inside into changes in forest condition (SFM Indicator for Criterion 2), nutrient availability, carbon sequestration and soil biota. This action is coordinated within the pan-European ICP Forests Level I network.

The RU states that a repetition of the vegetation and deadwood surveys would be beneficial for many aspects.

Inventory of soil organic matter pools (F. Hagedorn) to improve soil carbon cycle models.

The RU (K. Meusburger) encourages the investigation of physical soil properties at greater soil depths, forest stand (LAI, phenology) and spectral ground-truthing for remote sensing data necessary to gain a better basis for water budget modelling and upscaling drought effects

The RU has some interest in investigating tree nutrition status and its changes through either foliar sampling or bark sampling, e.g. every 15–30 years.

Support and resource availability.

- The RU (S. Zimmermann) is carrying out a repetition of the Soil Inventory on the 8 x 8 km grid, and which will be financed by BAFU (Sections Soil and Forests)
- The RU can carry out up to about 50 soil pit investigations (physical, chemical analyses) every year in total (all projects) with its own means.
- The RU runs an archive for soil and plant tissue samples (“Pedothek”); it can provide subsamples from past sampling campaigns and store future samples.
- The RU runs facilities for chemical analyses of plants and soils and assessing soil biota biodiversity.
- The RU can provide methodological support for one-time or continuous LAI measurements.
- The RU could contribute to the development of a sound design for “minimally invasive in-situ sampling of soil solution” and of “soil coring”.
- The RU could coordinate (workshop) activities with a link to the soil inventory. The RU has the knowledge to do water budget modelling for sample plots.

9 Research Unit Land Change Science

Christian Ginzler

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

The Remote Sensing group is already an active part in the NFI programme. We are very much interested in linking and explaining measurements and estimations in-situ with remote sensing data from various platforms (terrestrial, UAV, airplane, satellite). The more in-situ data available – in addition to the operational NFI data catalogue – the better.

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

We want to link close-range and non-close-range remote sensing data to in-situ measurements on e.g. trees/vegetation/soil/microclimate to upscale the plot-based data/measurements (medium term).

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

The scale of interest is the national scale. We want to get/have collected in-situ data representative of the various forest ecosystem types in Switzerland.

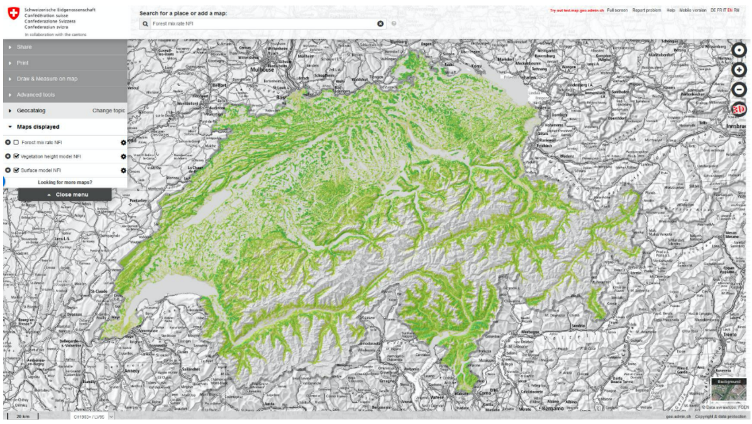


Figure 1: High resolution country wide remote sensing products to be linked with temporal high resolution in-situ data on a subgrid of the NFI.

Statistical requirements (if any) in terms of precision of status and change estimates.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

The collection of high-resolution close range remote sensing data on NFI plots is currently being tested and developed and could be used in NFI6. In addition to the operational NFI field data catalogue, more frequent data on phenology would be great (e.g.phenocams). Consensus needs to be reached with the NFI program on how to install small measurement equipment on the NFI interpretation plots.

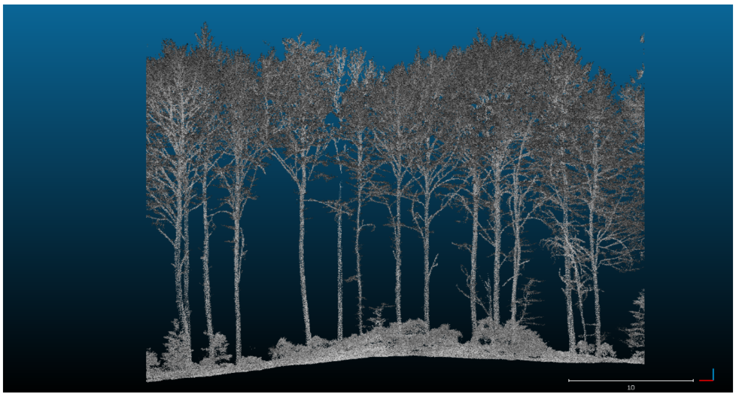


Figure 2: Example of high resolution close range remote sensing data on a test plot of the NFI.

Figure 3: Example of a pheno – image every e.g. week close to the NFI plot.

Support and resource availability.

Mainly within the NFI framework (to be discussed and negotiated within the NFI team). Pilot tests and the development of protocols could be done in ongoing projects (e.g. SILVA, CENTURION, FNEWs) on forest disturbance.

10 Research Unit Biodiversity and Conservation Biology

Rolf Holderegger, Ariel Bergamini

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

The biodiversity of forests, at all levels of biodiversity including habitats, species, genes, interactions and traits, and diverse groups of organisms, such as vertebrates, especially birds, bats, insects, trees and vascular plants, bryophytes, fungi with mycorrhiza and lichens, is a key topic of the RU Biodiversity and Conservation Biology. Our goal is the development and preservation of forest biodiversity by testing theories, understanding drivers, coming up with management implications and giving advice to practitioners/stakeholders.

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

- Scientific questions
    - How do biotic and abiotic variables affect forest biodiversity and functional traits? (making better use of existing data from NFI, WSL and beyond).
    - What are the genomic adaptations of forest trees and functional reactions of mycorrhiza to environmental changes, such as climate change and drought?
- Applied questions:
    - How do different types of forest management affect forest biodiversity and forest structure?
    - How does biodiversity develop and how is it represented in common and special forests (Naturwald- und Sonderwaldreservate, rare forest types), the latter being under-represented in current monitorings.

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

We are mainly interested in the scale of Switzerland, biogeographic regions and different elevations.

Statistical requirements (if any) in terms of precision of status and change estimates.

We are mainly interested in longer-term change. Hence, annual measurements are not necessary. However, after extreme events annual measurements on diverse groups of organisms (not only trees) would be important. Annual monitoring would also ask for in-situ measurements of environmental data (i.e. equipment on LFI-plots) in order to make full use of annual data.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

More biodiversity measurements on organismal groups other than trees are needed. If proxies for biodiversity are used, a strong correlation between the proxies and real biodiversity data has to be proven under a range of environmental conditions (validation). Better representation of environmental space is needed.

Support and resource availability.

We offer:

- Distribution data from the data centres Swiss Fungi and Swiss Lichens.
- A significant number of plots for Red List assessments of the data centres are next to NFI plots.
- The programme “Monitoring of Nationally Important Habitats WBS” contains 800 plots from riparian forests (including Auenwald).
- Insect database (784,000 datasets, 8900 taxa)
- Species specialists for mammals, bats, birds, insects, vascular plants, bryophytes, fungi, mycorrhiza and lichens.
- Experience with forest biodiversity monitoring (including environmental DNA).
- Knowledge on relationships between forest structure and biodiversity (including LiDAR).
- Adaptive genomics of trees.
- Biodiversity modelling.
- Knowledge on conservation biology and implementation in forests.

11 Research Unit Community Ecology

Marco Conedera, Anita Risch, Charlotte Grossiord, Peter Bebi

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

We consider NFI a very good monitoring programme providing fundamental information and data on Swiss forest conditions and evolutionary trends.

We think there is a need to work on two different levels:

- Enhancing the traditional NFI survey by adding / improving the precision of selected single parameters, and providing georeferenced information of annual stress factors at the plot level.
- Defining ad-hoc subnets (on a project basis) to deepen our understanding of the effects of particular events on the forest (e.g. drought 2018).

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

- Evolution of key forest parameters related to a forest service (e.g. protection forest).
- Evolution of specific iconic tree species that face problems under the present climatic and environmental conditions (e.g. the chestnut tree in the southern Alps).
- Impact of specific abiotic stressors (drought, heat and VPD).
- Forest regeneration and future forest dynamics.

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

- Single Swiss regions, including the mountain regions as a whole.
- Specific (at least locally) dominant tree species.
- Specific forest types (e.g. protection forests).

Statistical requirements (if any) in terms of precision of status and change estimates.

No particular needs.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

At the plot or interpretation area level:

- Parameters related to protection against natural hazards (mostly at the stand level, i.e., 50 × 50 m):
    - Additional information on terrain roughness and deadwood (relevant for rockfall and snow movements (e.g. spatial arrangement, dimension, decomposition stage of logs and root plates).
    - Further development of remote sensing methods and related field verifications generally have a high potential to improve the assessment and quantification of protection effects against natural hazards.
    - Nice to have: additional soil data related to soil stability and shallow landslides (geotechnical soil classification).

- Re-assessing red wood ant species ID in NFI6 (in NFI4 species ID & nest counts; in NFI5 only nest counts)

At the tree level:

- We strongly suggest to (re)include the following parameters:
  - Origin of the tree (gamic or agamic).
  - Social position (dominant, codominant, dominated, suppressed), which cannot be completely substituted by the position in the stand layer.
  - Next neighbouring tree for sample tree at the plot margin (distance from focal tree, height, DBH, species).

Support and resource availability.

We think additional resources should be targeted.
We are willing to cooperate in the acquisition of additional funds on common projects, as well as in exchanging with ongoing work, for instance the remote sensing based assessment of forest structure and protection functions, which may be helpful for the further development of Swiss AIM.

12 Research Unit Economics and Social Sciences

Tessa Hegetschweiler, Tobias Schulz

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

Yes, we are interested! AIM provides the possibility to combine forest visitor monitoring with data from forest plots and will help us build up forest visitor monitoring in Switzerland.

It also creates an opportunity to evaluate the effectiveness forest management interventions and of forest policy instruments motivating these.

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

- What are the visitor frequencies for these plots and which factors determine visitor frequencies? (medium term)
- In the long term, the monitoring of forest visitors, their frequencies, needs, preferences, behaviour and socio-demographics can enable us to detect trends and changes.
- Which goals and respective forest management strategy/interventions are pursued in the region and have been implemented on the plot for which reason. In the long-term, collecting reliable information about forest management interventions and their underlying motivation may allow an evaluation not only of forest management interventions but also of forest policy.

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

- Local level
  - Results can inform forest and visitor management at specific sites.
- Cantonal level
  - The results may allow a comparison between different forest types across cantons.
- Switzerland:
  - Patterns and trends concerning forest visitor numbers, needs, behaviour, etc. valid for all urban/recreational forests.
  - The results may allow a comparison between different forest types for entire Switzerland.

Statistical requirements (if any) in terms of precision of status and change estimates.

NA

This question cannot be answered at this point.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

- Visitor counts using automatic counters, e.g. continuously over one year, periodic updates.
- Forest visitor questionnaire survey.
- Forester/forest owner/expert questionnaire survey.
- Cantonal forest agencies questionnaire survey / interviews.
- Federal office questionnaire survey / interviews.

Support and resource availability.

- Expertise and project leadership by permanently employed WISOZ members.
- Human resources needed for carrying out specific projects.
- Financial resources needed for equipment and surveys.

13 Research Programme LWF

Arthur Gessler

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

LWF conducts long-term monitoring and tries to continue with existing methods and implement modern methods, such as physiological remote sensing. There is a high complementarity between LFI, LWF and other monitoring programmes at WSL, and collaboration and complementary methods can be expected to increase the power of monitoring in future.

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

All measurements done on the Sanasilva and LWF plots will be continued.

- Impacts of air pollutants and nutrients on trees and ecosystems (>10 yrs).
- Drought impacts on tree species and ecosystems (> 10 yrs).
- Interaction between drought and air pollutants (> 10 yrs).
- Mortality mechanisms (5-10 yrs).

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

- Tree and stand scale (Sanasilva and LWF).
- Switzerland (Sanasilva).

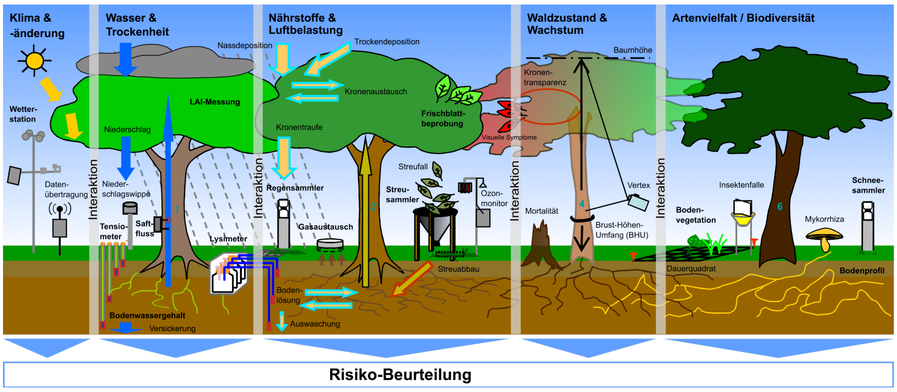
Statistical requirements (if any) in terms of precision of status and change estimates.

Highly variable and depending on the variable of interest.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

- Sanasilva:
    - Crown conditions (defoliation, colour, etc.), DBH, mortality, drone based information (1 × year); now on the 16 × 16 km grid, in future potentially on the 8 × 8 km grid.

LWF:



- New methods to be implemented in the monitoring scheme: drone based structural and physiological remote sensing.

Support and resource availability.

- Work will be done by LWF/Sanasilva field crews and database managers.
- Sharing of work between Sanasilva and LFI field crews needs to be discussed.

14 Research Programme Extremes

Niklaus Zimmermann

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

High-quality monitoring and inventory data are absolutely mandatory for drawing inferences about the influence of driving factors, such as climate and weather extremes and their immediate physical impacts on forest growth, mortality and regeneration. The identification of such extreme events and their extreme impacts are part of the programme we are currently developing, and a lack of data can lead to a lack of the capacity to answer essential programme questions (now or in the future).

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

Basically, anything that relates to extreme driver (combination) impacts on forests, as far as it can be measured from forest inventory data. This means for instance:

- Impact of extreme climatic events on forest annual growth, mortality or regeneration and its lag effects over the years following the extreme impact.
- Impact of extreme pest/infestation effects on annual forest growth, mortality or regeneration and its lag effects over the years following the extreme impact.
- Impact of severe cold (or combination of severely warm winter/cold spring) on forest growth, mortality or regeneration and its lag effects over the years following the extreme impact.

In other words, in the research relevant to the programme, (extreme) impacts of primarily direct drivers are targeted, and anything that can be measured (and varies) annually is of great importance to the programme. This includes: growth parameters of individual trees (including stem width and height increment, BAI or stem volume), regeneration from seedlings, and mortality of tree individuals. I understand that not all of these are measured on each individual stem per plot. But an annual resolution is key to identifying the impacts of extremes. The impacts (direct and lagged) of extremes on tree individuals cannot be quantified clearly from longer inventory cycles. Annual measurements well sampled along major environmental gradients are thus key.

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

Usually, I am interested both in a sound representation of Switzerland (ultimately, we make statements “for Switzerland”), but also in a sound representation of the major environmental gradients of Switzerland. The latter is key because we analyse most effects “in ecological space”, since we seek to assess the effects of environmental drivers on growth, mortality and regeneration, and it often clearly matters whether e.g. a drought occurs in a warm/dry or in a cold/mesic environment. With regards to the former (spatial domain Switzerland), it should also be possible to analyse data from larger regions of Switzerland alone, or to contrast them in their anomalies against other regions (e.g. North-Eastern compared with North-Western Switzerland) since some extreme impacts may primarily occur in specific regions only (e.g. windthrows, pest outbreaks, cold spells).

When it comes to designing an ideal extension of the existing monitoring network for annual measurements, I wish to repeat the need to represent Switzerland both spatially and environmentally. A sound representation of the environment of Switzerland for annual measurements not only helps ecological analyses and interpretation, but also means that the upscaling to larger regions from individual plots can be done with less uncertainty, if ecological variables are considered and not (only) geographic variables. This is the core projection from sample sites to the landscape. Ideally, thus, the core LFI design is left untouched. But instead of simply going to a coarser subnet for annual analyses, I suggest using a design that maintains the representation both of Switzerland and of important ecological gradients. This can be done e.g. by defining a coarse subgrid (e.g. 32 km) and then placing a few plots within that subgrid – across Switzerland – thus guaranteeing the coverage of the environmental variability spanned by the 1 (or 1.4) km base raster. There are endless possibilities to combine spatial with environmental representations in such subsampling, as indicated in Figure 1.

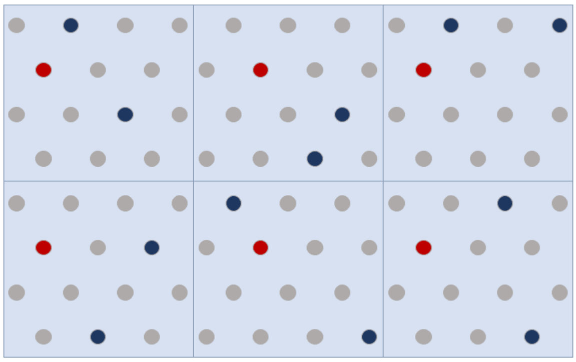


Figure 1: Example of a combined spatial (red dots) and environmental (blue dots) representation of sampling gradients across a study region. Here, the spatial representation is done by sampling always the same element of a finer grid (original LFI sampling grid) at a coarser spatial scale (light blue boxes). Therein, two sampling elements (plots) are selected to span ideally across the environment of the whole study area, but allocated such that each coarser domain (light blue box) has the same number of sample plots allocated.

Statistical requirements (if any) in terms of precision of status and change estimates.

I cannot easily answer this question. I can only say that with 10-year repeat intervals, the effect of extreme impacts cannot be measured well. Any subset of the LFI network sampled at an annual resolution would be a huge gain and improve the statistical power to identify impacts at the tree level.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

All samples I have suggested are within the non-destructive domain of classical inventory methods. However, I could imagine to additionally do a tree-ring based assessment of past growth, e.g. by taking a tree-ring core on a subset of trees per LFI plot. This is also done e.g. in other national inventories. In the US, the last 10 years are taken on all plots on all or a subset of trees, and in Canada, the age of a subset of trees is measured by tree-ring cores on all inventory plots. Such datasets are of utmost value for at least reconstructing past impacts, be it from variably “normal” or single “extreme” events. But such measurements are not of much help to cover future effects.

Support and resource availability.

Very generally, I can offer analytical and design support. This includes complex analytical pathways to upscale from plots using our modelling expertise. In addition, we have experience in designing analysis from the idea stage to writing them up in the form of high-impact papers. This is what I can easily offer. We do not have many resources on our own, but lots of enthusiasm and willingness to cooperate.

15 WSL Biodiversity Center

Catherine Graham, Rafael Wüest Karpati

Position of the RU / Programme / Centre / Initiative at WSL with respect to Swiss AIM and its starting vision.

The WSL Biodiversity Center has great interest in AIM. Forests are undoubtedly important in generating and maintaining biodiversity in Switzerland and globally. AIM has the potential to provide unique data that can serve to answer a multitude of outstanding, cutting-edge questions in Biodiversity research.

Key scientific questions: current and foreseen for the medium (5–10 yrs) and long term (>10–50 yrs).

The Center is not in a position to outline specific questions, as we think these should be generated by the Scientific Community of the Center. However, broadly speaking, AIM will allow investigations on how biodiversity is changing given ongoing environmental and anthropogenic change across seasons and among years. It is the temporal frequency (short sampling intervals ≤ 1 yr combined with the long-term aspect of collected data that would render AIM data as particularly unique and valuable, especially if it covers the large Swiss environmental gradients well.

Scales of interest (spatial, temporal, ecological, environmental) and/or statistical inference.

- Spatial: local (plot-scale) to country-wide.
- Temporal: cross-seasonal to annual across many years.
- Environmental: spanning and regularly sampling the large Swiss environmental gradients, following a robust sampling design.

Statistical requirements (if any) in terms of precision of status and change estimates.

Such estimates are inherently difficult to predict/simulate for biodiversity change. Also, the requirements towards data will depend on the specific question (which we deliberately did not spell out). Also, data quality is of major importance here, and biodiversity estimates are known to be associated with substantial uncertainties. Therefore, we cannot formulate an expected precision of estimates. However, we would like to emphasise that a robust sampling design allows the calculation and further consideration of uncertainties, which is important and is becoming a standard in biodiversity research.

Related data needs: attributes to be measured, plots, instruments, trees, destructive sampling.

- We encourage sampling of a wide range of taxa in terms of biodiversity, i.e. to extend the trees and shrubs to include all vascular plants, and to also assess animals (e.g. birds, insects) and fungi.
- Environmentally stratified sampling: it is of ample importance that the major axes of environmental variation in Switzerland are well covered by AIM if we want to reliably answer ecological questions (not only related to biodiversity, but in general). This can be achieved with a robust sampling design that ensures sufficient sampling of environmental conditions – there is ample experience at WSL on this topic.
- Destructive sampling: minimal intervention should be allowed. Especially for genetic sampling and for coring tree-ring samples, as these have the potential to bridge between questions and research topics.

- Sampling frequency: an annual scheme would be the absolute minimum for sampling. Many taxa (see our suggestion to widen the range of investigated taxa) would require several samples per year. Also: multiple samples per year, e.g. for plants, allow to assess seasonal abundance/diversity/phenology patterns and mid- to long-term changes in these.
- We further suggest recording certain environmental parameters in situ by setting up (semi-)permanent installations.

Support and resource availability.

- We cannot support AIM via financial resources. But we are happy to connect AIM with WSL experts on biodiversity in general, in environmentally stratified sampling, as well as taxonomic specialists and others. We are also happy to support and organise workshop(s) that support AIM in tailoring the inventory to meet certain needs of the biodiversity community.

Part 3 Annexes

Annex 16. Workshop programme

08:45 – 09:00 Welcome and "round table tour".

09:00 – 09:45 Origin of the initiative and background information on NFI (12 talk + 3 min direct Q&A each).

- Introduction: what is the Swiss AIM and why it is necessary (M. Ferretti).
- The Swiss NFI: design and organization (M. Hägeli, C. Fischer).
- The Swiss NFI: attributes, methods, data models (M. Abegg, B. Traub, E. Thürig).

09:45 – 10:30 Input, scientific questions and demands from Research Units, Part 1 (12 talk + 3 min direct Q&A each).

- Forest Dynamics (T. Wohlgemuth; G. von Arx).
- Forest health and biotic interactions (E. Brockerhoff; V. Queloz).
- Soil and Biogeochemistry (P. Waldner; K. Meusburger).

10:30 – 11:00 Coffee break - Pause

11:00 – 12:00 Input, scientific questions and demands from Research Units, Part 2 (12 talk + 3 min direct Q&A each).

- Land Change Science (M. Bürgi; C. Ginzler).
- Biodiversity and Conservation Biology (R. Holderegger; A. Bergamini).
- Community Ecology (M. Conedera; P. Bebi).
- Economics and Social Sciences (T. Hegetschweiler).

12:00 – 13:30 Lunch break – Pause

13:30 – 14:15 Input, scientific questions and demands from Programs, Initiatives, Centers (12 talk +3 min direct Q&A each).

- LWF (A. Gessler).
- Extremes (N. Zimmermann).
- Biodiversity Center (C. Graham; R. Wüest Karpati).

14:15 – 15:00 Discussion and next steps.

- Swiss AIM: a possible roadmap (M. Ferretti).

Annex 17. List of participants (alphabetical order).

Prog. no.	RU / Program	Name	Status
1	NFI (Program)	Meinrad Abegg	Confirmed
2	Community Ecology	Peter Bebi	Confirmed
3	Biodiversity and Biological Conservation	Ariel Bergamini	Confirmed
4	Forest Health and Biotic Interactions	Ecki Brockerhoff	Confirmed
5	Land Change Science	Matthias Bürgi	Confirmed
6	Community Ecology	Marco Conedera	Confirmed
7	Forest Resources and Management	Marco Ferretti	Confirmed
8	NFI (Program)	Christoph Fischer	Confirmed
9	LWF (Program)	Arthur Gessler	Confirmed
10	Land Change Science	Christian Ginzler	Confirmed
11	Biodiversity Center	Catherine Graham	Confirmed
12	NFI (Program)	Martin Hägeli	Confirmed
13	Economics and Social Sciences	Tessa Hegetschweiler	Confirmed
14	Biodiversity and Biological Conservation	Rolf Holderegger	Confirmed
15	Forest Soils and Biogeochemistry	Kathirn Meusburger	Confirmed
16	Forest Health and Biotic Interactions	Valentin Queloz	Confirmed
17	Forest Resources and Management	Esther Thürig	Confirmed
18	NFI (Program)	Berthold Traub	Connfirmed
19	Forest Dynamics	Georg von Arx	Confirmed
20	Forest Soils and Biogeochemistry	Peter Waldner	Confirmed
21	Forest Dynamics	Tom Wohlgemuth	Confirmed
22	Biodiversity Center	Rafi Wüest Karpati	Justified
23	Extremes (Program)	Niklaus Zimmermann	Confirmed