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Ecosystem Studies in a Limestone Area - Achenkirch Altitude Profiles. Introduction and Objectives

By

F. HERMAN & S. SMIDT¹⁾

Key words: Northern Tyrolean Limestone Alps, forest ecosystem research, altitude profiles, rhizosphere.

S u m m a r y

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Since 1990 the stress on mountain forest ecosystems has been investigated in the framework of the interdisciplinary project called "Ecosystematic Studies in the Limestone Alps - Achenkirch Altitude Profiles". The subject matter report presents results from the rhizosphere. Apart from the description of the area of the Limestone Alps and several stressors, biomonitors were used for environmental assessment. The impacts of forest pasture were evaluated using vegetational, root-ecological and soil biological methods. Based on country-wide investigations carried out by the Federal Forest Research Centre (Austrian Forest Damage Monitoring System, Bio-Indicator Grid), the threat to the area of the Limestone Alps (forest ecoregions 2.1 and 4.1) was assessed and modelling was applied.

I n t r o d u c t i o n

In Europe, forests are exposed to the combined effects of numerous harmful influences. As there is no general cause-effect relationship to be held responsible for forest damage and additional regional and time-related causes of damage are much more complex than was originally expected, stressors and their effects need to be investigated on a broad basis.

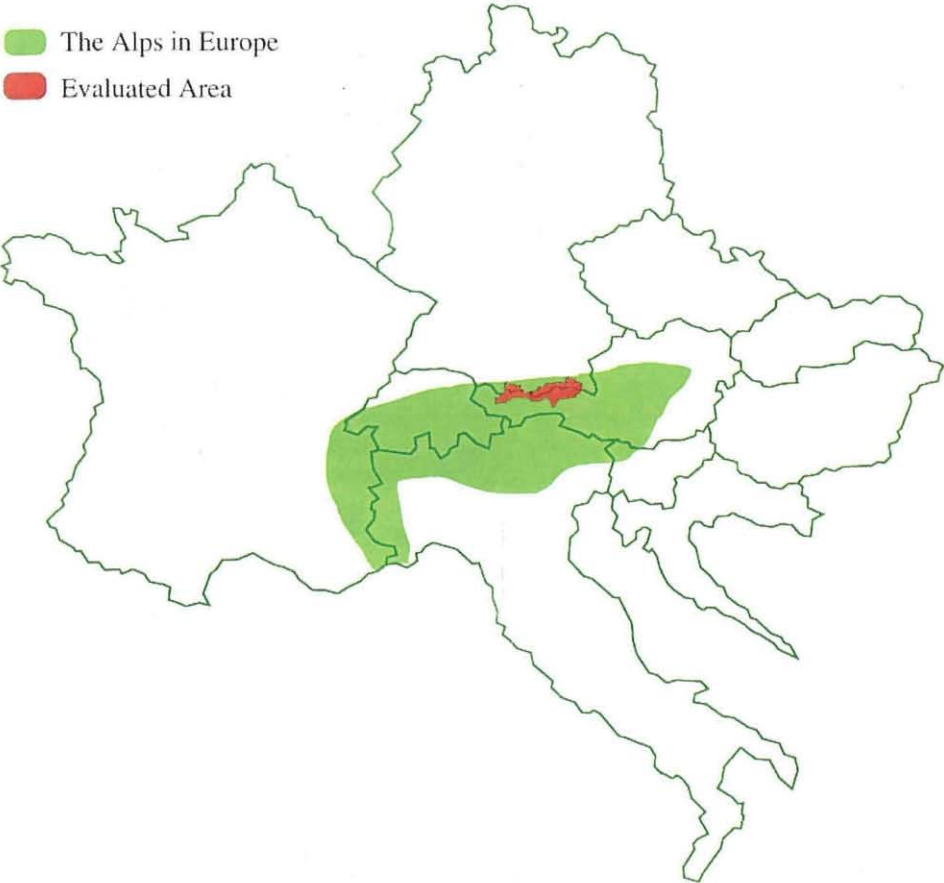
¹⁾ Institute of Air Pollution Research and Forest Chemistry of the Federal Forest Research Centre, Seckendorff-Gudent-Weg 8, A-1131 Vienna, Austria.

The calculations in this report pertain to the Northern Tyrolean Limestone Alps, which are part of the European Alps (Fig. 1.). The protection of the Alpine regions should be given highest priority not only because of the commercial and other benefits that the area offers and that are sometimes over-exploited for tourism, but also because the alpine area is one of the largest coherent ecoregions of Europe and a Noah's ark for endangered species and ecosystems.

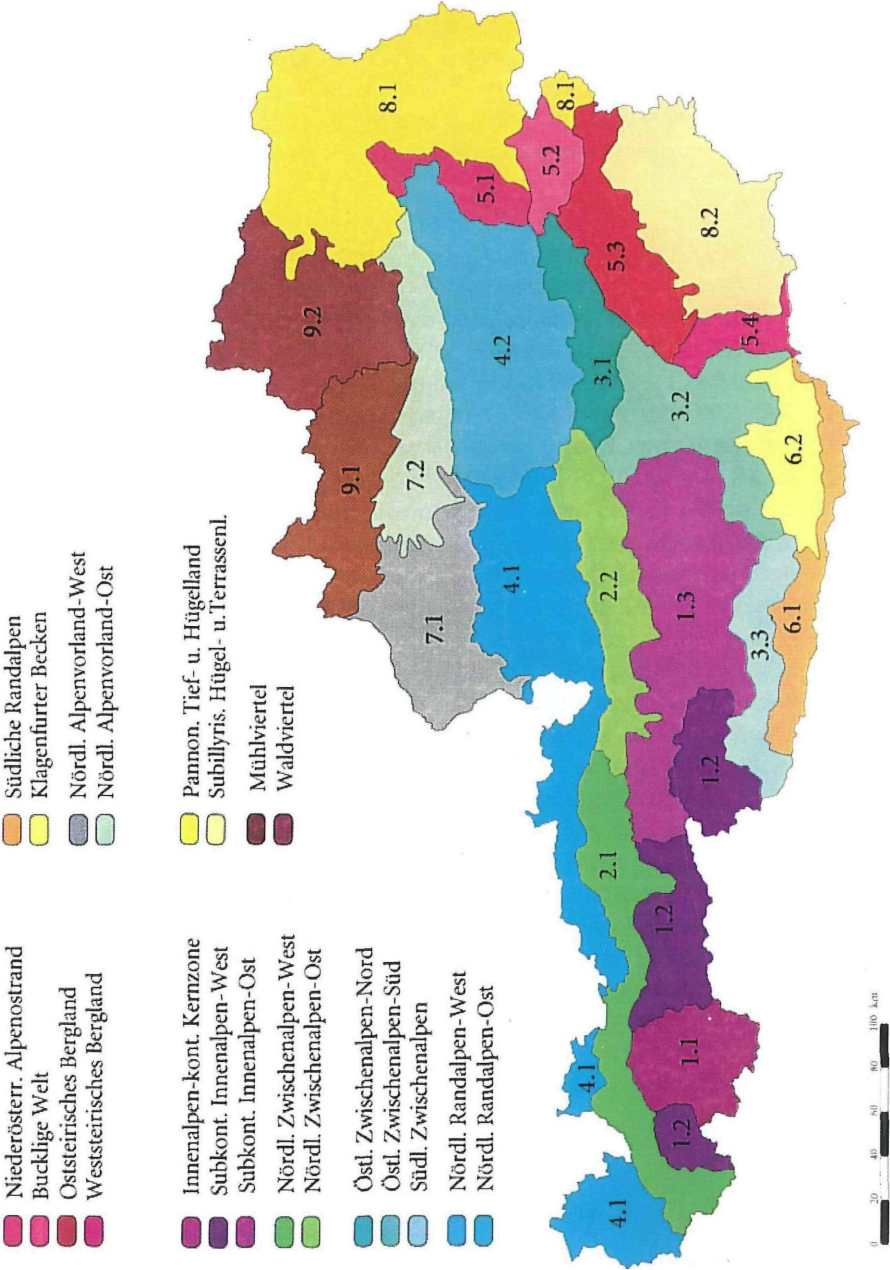
Monitoring and ecosystematic investigations in Europe with special consideration of Austria

Following the discussion about the causes of new-type forest damage, numerous monitoring programmes have been initiated in Europe since the early eighties (PROJEKTGRUPPE BAYERN ZUR ERFORSCHUNG DER WIRKUNG VON UMWELTSCHADSTOFFEN 1991, COMMISSION OF THE EUROPEAN COMMUNITIES 1992, FEDERAL OFFICE OF ENVIRONMENT, FORESTS AND LANDSCAPE 1992, INNES 1993, MINISTERIUM FÜR UMWELT, RAUMORDNUNG UND LANDWIRTSCHAFT 1993, COMMISSION OF THE EUROPEAN COMMUNITIES 1994, FLÜCKIGER & BRAUN 1994). Investigations covering the entire area of Austria were carried out on the basis of crown assessment and related investigations (Austrian Forest Condition Inventory, Forest Damage Monitoring System including Forest Soil Monitoring System, Bio-Indicator Grid; e.g. FEDERAL FOREST RESEARCH CENTRE 1991a, 1992a,b, STEFAN 1987, 1993). These all-Austrian investigations are monitorings and, based on selected additional parameters (e.g. sulphur and nutrient concentrations in needles and leaves, chemical soil and vegetation parameters), describe the current status and development of forests. However, it is not possible to arrive at conclusions regarding cause-effect relationships between harmful factors and injuries observed in forests. It takes a sophisticated screening of telling parameters to be able to alleviate stress symptoms before they cause visible damage. In Europe, the interdisciplinary investigations were partly carried out in the form of field experiments (e.g. COMMISSION OF THE EUROPEAN COMMUNITIES 1987, GKSS RESEARCH CENTRE GEESTRACHT 1988, 1992, NATIONAL RESEARCH PROGRAMME NP14+ 1991, FINNISH FOREST RESEARCH INSTITUTE 1992, PROJEKTGRUPPE BAYERN ZUR ERFORSCHUNG DER WIRKUNG VON UMWELTSCHADSTOFFEN 1993) and also within large-scale investigations under controlled conditions in fumigation chambers and open-top chambers (e.g. REHFUESS & BOSCH 1986, BLANK & LÜTZ 1990, KRUPA & ARNDT 1990). In Austria, interdisciplinary research projects in the field were carried out.

-  The Alps in Europe
-  Evaluated Area



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Numerous stressors were investigated and interpreted in the framework of interdisciplinary approaches (HALBWACHS 1982, BOLHAR-NORDENKAMPF 1989, RESEARCH INITIATIVE AGAINST FOREST DIEBACK 1992, FEDERAL FOREST RESEARCH CENTRE 1989a,b, 1990, 1991b, 1992c, 1995, HERMAN & SMIDT 1992, 1994, SMIDT & al. 1994).

The ecosystematic investigations in the Tyrol were initiated in the early eighties by the Federal Forest Research Centre because according to the surveys of the canopy status large forested areas of that Federal province were classified as stressed or damaged already at that time and the results are confirmed by surveys of the local canopy status (KREHAN & TOMICZEK 1992, AMT DER TIROLER LANDESREGIERUNG 1994).

In the entire region of the Tyrol the protection of stable and well-supplied forest ecosystems is an urgent necessity. As opposed to other alpine countries the population in the Tyrol has substantially increased over the past 100 years, which has caused a scarcity of the "resource living space". Only 13 % of the surface of the Tyrol are suited for permanent settlement; only about 4 % of the area is flat. Sometimes up to 900 people per km² live in this "net Tyrol"; and that area must provide space for living and working, agriculture and forestry, recreation and tourism, the latter being particularly important from an economic point of view (SCHEIRING, pers. comm.).

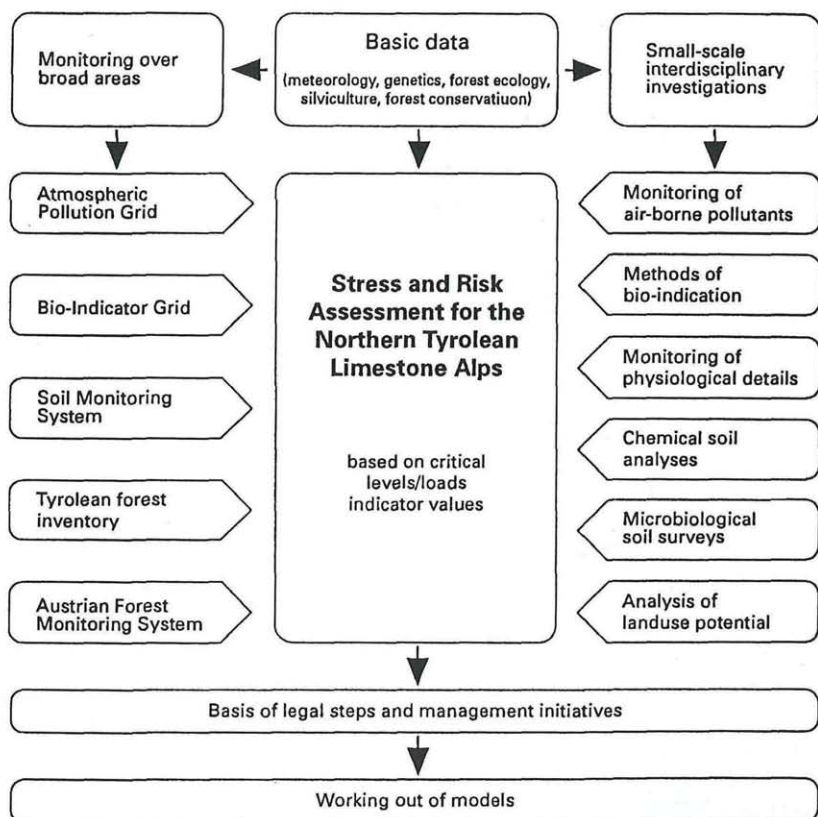
As is usually the case in mountainous areas, the status of the forests differed markedly as a consequence of specific stress patterns, both geographically and in respect of time. The causes of crown defoliation investigated in the frame of the Austrian Forest Condition Inventory and the Forest Damage Monitoring System in the Tyrol showed an increase of about 30 % to more than 40 % of the damaged area (total of heavily + moderately + slightly affected areas) from 1984 to 1988; from that year onward, this rate has almost permanently been 40 %. The Tyrolean forest inventory also shows that forest damage increased markedly in the Northern Alps (based on the percentage of damaged forest areas of more than 60 year old stands) compared to the investigations of 1984 and 1993, while the situation improved in the Inn Valley and deteriorated only slightly in the Central Alps.

Ecosystematic studies by means of altitude profiles in Austria/Tyrol

The establishment of altitude profiles made it possible to investigate several questions, especially those regarding stress at different altitudes, at the timberline and in protection forests. Cooperation with numerous working groups allowed an interdisciplinary interpretation of the results. Research activities focused on forests at relatively high altitudes where the protective function is of special importance.

In the Tyrol the interdisciplinary forest damage research of the Federal Forest Research Centre was started in the frame of the project of the "Zillertal Altitude Profile". The environmental data from three years of metering provided the basis of stress-physiological investigations in the following years. It was possible to deduce a risk prognosis and methods of early diagnosis. The investigations allowed many conclusions that are interesting for the reactions of the ecosystem to the impact of stressors and the evaluation of these reactions.

Table 1. Research approach aimed at stress and risk assessment for the Northern Tyrolean Limestone Alps.



The follow-up project "Achenkirch Altitude Profile" is based on the results from the Zillertal (as opposed to Achenkirch, quartz phyllite is the underlying bedrock in the Zillertal) and was started in 1990. Fig. 2 outlines the forest ecoregions 2.1 and 2.4, where the investigation profiles are located and which will be evaluated.

The project "Achenkirch Altitude Profiles"

The "ecosystem forest" in the investigation area can be described and assessed on the basis of the results from the basic data from the fields of silviculture, forest ecology, forest genetics, meteorology and air chemistry. More profound statements about the Northern Tyrolean Limestone Alps can be inferred when data from the all-Austrian investigations are incorporated. In the present project the assessment of the stress situation in the Limestone Alps was carried out by using the results of the small-scale interdisciplinary investigations (BOLHAR-NORDENKAMPF 1989, PUXBAUM & al. 1991, SMIDT & al. 1991, FEDERAL FOREST RESEARCH CENTRE 1992d, SMIDT & HERMAN 1994, SMIDT & al. 1994) and the results of all-Austrian monitoring systems (STEFAN 1991, FEDERAL FOREST RESEARCH CENTRE 1991a, 1992a,b). Critical Levels, Critical Loads, parameters suited as indicators and data from the landuse potential analysis are incorporated. It is planned to use models to combine all the results and knowledge so obtained into a basis of regeneration, rehabilitation and management initiatives. Considering these points, it seemed reasonable to broaden the research approach (Table 1).

Objectives

The project focuses on the following issues and objectives:

- **Characterization of the area of the Limestone Alps** in respect of forest ecology, silviculture, genetics, forest conservation, and meteorology;
- **Environmental Monitoring** (integrated monitoring) aimed at the assessment of stress and stress tolerance of individual areas on the basis of the legal limiting values, guidelines and targets for limiting values; methods of bio-indication aiming at the characterization of pollution stress;
- **Deduction of indicator values suited to characterize the physiological condition** with a view for finding diagnostic methods which can be used also in the practice at a reasonable expense and from which numeric data can be deduced that allow the assessment and/or classification of stress risks;
- **Contributions on questions of protective forests and forests in alpine uplands** aiming at a risk assessment for that important type of forest and at possible solutions to minimize the risk;
- **Contributions on forest pasturing** aimed at a scientific assessment of the influence of pasturing on soil stability, natural regeneration, and biodiversity;
- **Contributions on the formulation and/or refinement of critical levels and critical loads** in order to identify stress situations caused by pollution input on

the basis of long-term field investigations and so to provide the basis for appropriate legislation;

- **Use of models** for the combination of local risk factors and the provision of a basis for practice-oriented measures aimed at the identification and avoidance of potential risks.
- The **risk assessment for the area of the Northern Tyrolean Limestone Alps** is to be based on the combination of results from environmental monitorings (monitoring surveys, integrated monitoring, methods of bio-indication), the interpretation of indicator values characterizing the physiological condition (components of the antioxidative system, detoxification enzymes, lipoids, photosynthetic measurements), and contributions on questions of protection forests and forest pastures (examination of mycorrhizae and afforestation experiments in areas used for forest pasturing) as well as on the use of models (including atmospheric pollution, soil, and forest inventory data).

Scope of investigation

The basic structure of the project remains the same as at the beginning of the project (HERMAN & SMIDT 1994) and has been expended by the results from completed projects and the resulting findings and / or questions. Table 2 shows the scope of investigations.

Area of investigation and sample plots

The area of investigation is located at the rim of the Northern Tyrolean Limestone Alps (spruce, fir, beech forest community). The profiles established in the area of investigation differ from each other in respect of silvicultural conditions and stress situation. Especially forests at higher altitudes are characterized by fewer mixed stands, which is due to centuries of forest pasturing on sensitive soils. Conflicts of use are among other things due to the intensive summer and winter tourism in the Achenental and the wildlife management. The geographical location of the area of investigation and the sample plots are shown in Fig. 3.

Table 2. Investigations carried out in the area of the Achenkirch Altitude Profiles (total scope of investigation; only partly treated in the present volume).

Container stations: CK: Christlumpkopf; CA: Christlumlalm; TB: Talboden; MÜ: Mühleggerköpfl (sample plot 8)

Sample plots 1-6: Christlum profile, Sample plots 7,9 and 10: Schulterberg

Station number Container station	CK	1	1A	2	CA	3	4	5	6	TB	7	9	10	8	10
m.a.s.l.	1758	1420	1400	1320	1250	1240	1140	1050	070	830	1080	1220	1030	820	820
Air quality measurements															
SO ₂ , NO _x , O ₃	●				●					●				●	
Chlorinated hydrocarbons															
Hydrocarbons											●	●	●		
Deposition measurements															
Open field	●		●		●			●		●				●	
Throughfall			●					●							
Dry deposition	●		●		●			●		●					
Occult deposition (fog)	●				●					●					
Meteorological measurements and Investigations	●				●					●	●	●	●	●	
Leaf investigations															
Nutrients & pollutants, biochemical parameters		●	●	●		●	●	●	●		●	●	●	●	●
Chlorocarbons and protein content		●	●	●		●	●	●	●					●	
Peroxides												●	●	●	●
Fatty acids		●	●	●		●	●	●	●		●	●	●	●	●
Photosynthetic measurements									●		●	●	●	●	
Anatomy and morphology		●	●	●		●	●	●	●		●	●	●	●	●
Biometry											●	●	●	●	●
Forest ecological Investigations															
Forest communities and sites		●	●	●		●	●	●	●		●	●	●	●	●
Vegetation		●	●	●		●	●	●	●		●	●	●	●	●
Root ecology											●				
Soil and soil biology Investigations															
Nutrients and pollutants		●				●		●			●	●	●	●	●
Microbial activity; biomass		●				●		●			●				
Fungal communities		●	●	●	●	●	●	●	●		●				
Mycorrhizae		●				●		●			●				

Further bioindication methods																
Cytogenetic bioindication			●	●	●		●	●	●	●			●	●	●	●
Heavy-metal content of mosses													●	●	●	●
Heavy-metal content of fungi													North profile			
Lichen mapping		●	●	●			●	●	●	●						●
Bark analyses		●	●	●			●	●	●	●			●	●	●	●
Needle waxes		●	●	●			●	●	●	●			●	●	●	●
Genetic analyses							*									
Population genetics													●	●	●	●
Forest-pathological investigations		●	●	●			●	●	●	●			●	●	●	●
Crown thinning		●	●	●			●	●	●	●			●	●	●	●
Blooming and fructification of trees													●	●	●	●
Forest inventory	Area of Achenkirch															
Forest pasture													●			
Analysis of landuse potential	Area of Achenkirch															

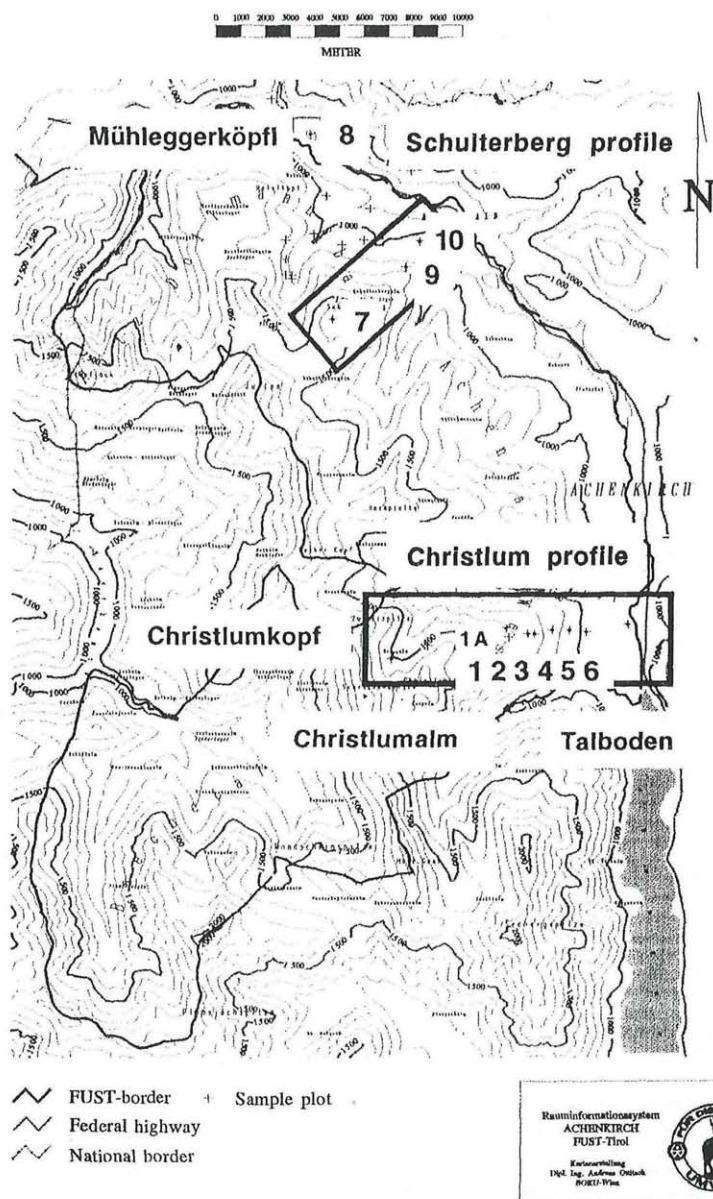


Fig. 3. Area of investigation and sample plots.

Individual contributions presented in this volume

In this volume the area of the Limestone Alps will be described, focusing on the rhizosphere. First results of the investigations and results from the "phyllosphere" have already been published (HERMAN & SMIDT 1994, SMIDT & al. 1994). This volume will also offer a first risk assessment regarding the forest ecoregions 2.1 and 4.1, which cover almost the entire area of the Northern Tyrolean Limestone Alps.

Characterization of the Northern Tyrolean Limestone Alps

- The genetic characterization of spruce is to indicate the degree of adaptedness or the adaptability of trees.
- The nutrient supply of the soils is described and evaluated by the all-Austrian results.
- The forest communities and sites of the area of investigation are characterized on the basis of the plant-sociological investigations. The effects of non-timber uses on the forest communities are described.
- The diversity and relative number of species of basidiomycetes will be used as a basis for potential future changes.
- Microbiological soil parameters are used to characterize different altitudinal zones.
- Forest sites are assessed from the status of mycorrhizae and fine roots.
- Mycorrhizae are identified by molecular biological techniques, which may allow a quicker identification and, therefore, a more precise assessment of site quality.

Contributions on risk assessment in the Northern Tyrolean Limestone Alps based on all-Austrian monitoring systems, survey networks and model approaches

- Of the parameters investigated in the course of the Austrian Forest Survey those are selected and quantified for the forest ecoregions 2.1 and 4.1 that indicate stress. The results of the Forest Function Plan ("Waldentwicklungsplan") have been incorporated in the assessment.
- By using additional all-Austrian investigations (Austrian Bio-Indicator Grid, Forest Soil Monitoring System) the pollution impact of the Northern Tyrolean Limestone Alps is described.
- On the basis of the nutrient analyses made in the framework of the Austrian Bio-Indicator-Grid the nutrient status of the bio-indicator trees is determined and evaluated.
- Punctual long-term measurements of gaseous air-borne pollutants and wet depositions are made; on the basis of Critical Levels and Critical Loads the results of such measurements are assessed using model approaches.

Contributions on risk assessment in the Northern Tyrolean Limestone Alps based on investigations in the area of Achenkirch

- Methodic approaches for the solution of landuse conflicts are described.
- The flux of elements (sulphur, nitrogen, proton inputs) under the canopy and investigations of the soil water are among other things used to assess critical inputs and the role of nitrogen as a harmful or limiting factor.
- The pesticide content of wet precipitation is evaluated.
- By means of a comparison of the total heavy-metal input and the variable content of the soil the suitability of heavy metals as indicators of atmospheric pollution is examined.
- With the help of the heavy-metal content of basidiomycetes the suitability of basidiomycetes as bioindicators is tested.
- The appropriateness of the method of the quantification of chromosome aberrations for the cytogenetic bioindication of harmful influences on spruce roots is examined.
- The influence of forest pasturing on the herb layer and its root substance, on the soil-microbial activity of the mycorrhizae and the growth of seedlings will be examined.

Institutes involved

- Federal Forest Research Centre (Institute of Silviculture, Institute of Forest Genetics, Institute of Forest Ecology, Institute of Forest Protection, Institute of Forest Inventory, Institute of Air Pollution Research and Forest Chemistry).
- Vienna University of Technology (Institute of Analytical Chemistry; Institute of Applied Botany, Technical Microscopy und Organic Row Material Studies; Institute of Biochemical Technology and Microbiology).
- Vienna University of Agriculture (Institute of Forest Ecology, Centre of Environment and Nature Conservation, Institute of Forest Economy and Forest Economic Policy).
- University of Graz (Institute of Plant Physiology).
- University of Innsbruck (Institute of Microbiology).
- Centre of Meteorology and Geodynamics.
- Federal Institute of Alpine Agriculture, Gumpenstein.
- GSF Research Centre of Environment and Health, Munich (Institute of Biochemical Plant Physiology and working group EPOKA).
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Autor(en)/Author(s): Herman F., Smidt Stefan

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