Site description
LTER ZÖBELBODEN

Vienna, 2011-11-02

United Nations monitoring framework

The ecosystem monitoring site „Zöbelboden“ is Austria´s contribution to the International Cooperative Programme (ICP) „Integrated Monitoring of Air Pollution Effects on Ecosystems“ (IM). This ICP is the most recent of 6 ICPs within the Working Group on Effects of the UN-ECE „Convention on Long-Range Transboundary Air Pollution“.

The overall aim of integrated monitoring was originally to determine and predict the state and change of terrestrial and freshwater ecosystems in a long-term perspective with respect to the impact of air pollutants, especially nitrogen and sulphur. This was to provide one basis for decisions on emission controls and assessment of the ecological impact of such controls within the UN ECE Convention on Long-range Transboundary Air Pollution. However, the full implementation of the Integrated Monitoring Programme will provide quantitative data on the ecological effects of tropospheric ozone, heavy metals and persistent organic substances. Implementation of the Programme will be a major contribution to the international data requirements for examining the ecosystem impacts of climatic change, changes in biodiversity and depletion of stratospheric ozone. A primary concern is the provision of scientific and statistically reliable data that can be used in modelling and decision making.

While the other ICPs are aiming at the monitoring of air pollution effects on forests, inland waters, crops, materials etc., the „Integrated Monitoring“ is putting emphasis on the simultaneous measurement of physical, chemical and biological properties of an ecosystem over time and across compartments at the same location. In practice, monitoring is divided into a number of sub-programmes which are linked by the use of the same parameters (cross-media flux approach) and/or same/close stations (cause-effect approach).

In the hierarchy of monitoring activities, the multi-disciplinary Integrated Monitoring programme represents the highest level in terms of number of parameters, thus, the spatial coverage being limited. The IM-network covers big parts of Europe, representing a source of information for comparison of complex and multiple effects across climatic gradients as well as geological and ecozone boundaries. However, in order to provide policy related information, the ICP IM is dependent on the existence of monitoring activities at a lower level in the hierarchy, reflecting the regional variation.

LTER-Zöbelboden, Long-Term-Ecological Research

LTER networks are networks of scientists, institutions and research infrastructure for ecological research with a focus on long-term processes. National and international efforts to combine the infrastructure of highly instrumented monitoring sites more effectively with ecosystem research led to the establishment of the Austrian and European LTER network. In 2006 the Zöbelboden site became part of LTER Austria and LTER Europe. Today it is also one of the core EU infrastructures of highly instrumented sites within the EU EXPEER initiative. Researchers from across Austria and Europe use these sites for their studies when long-term data, expensive infrastructure or complex research logistics are on demand.

Methodological approach and main objectives

- using the whole of small catchments/ecosystems as environmental monitors (some tens to some hundreds of hectares)
- simultaneously monitoring both biogeochemical trends and biological responses
- long-term monitoring of inputs, turn over and output of substances (covering all types of input/output)
- seeking to separate the noise of natural variation, including succession, from the signal of anthropogenic disturbance
- quantifying which concentrations/loads are causing which effects (development and evaluation of effect-based thresholds)
- developing and applying tools, e.g. models, for regional assessment and prediction of long-term effects.

In order to fulfil these objectives the site had to

- be located in a background area (absence of local pollution sources)
- be representative for a larger region (upscaling)
- be protected from anthropogenic disturbances
- meet the basic requirements for installing monitoring infrastructure (accessibility, power supply etc.)

The location of LTER Zöbelboden in the Northern Limestone Alps was selected because these karst areas are exposed to disproportional long-range air pollution. And karst areas are the main resource of drinking water for the Austrian population. Moreover, LTER Zöbelboden is part of the Kalkalpen national park, so that human impact is minimized.

Location, geology, climate, management

LTER Zöbelboden has a size of 90 ha and is situated in the northern part of the national park "Northern Limestone Alps", approximately 50 km south of Linz (N 47°50'30", E 14°26'30") (www.umweltbundesamt.at/im). The altitude ranges from 550 m to 956 m a.s.l.. The main rock type is Norian dolomite (Hauptdolomit), which is partly overlain by limestone (Plattenkalk). Due to the dominating dolomite, the watershed is not as heavily karstified as limestone karst systems, but shows typical karst features, such as conduits and sink holes. These conduits and sink holes provide pathways for rapid water flow and quick response times to water input at the soil-bedrock interface. The long-term average annual temperature is 7.2° C. The coldest monthly temperature at 900 m a.s.l. is -1°C in January, the highest is 15.5°C in August. Annual rainfall ranges from 1500 to 1800 mm. Monthly precipitation ranges from 75 mm (February) to 182 mm (July). Snowfall occurs between October and May with an average duration of snow cover of about 4 months.

From the start of the project in 1992 onwards, forest management has been restricted to single tree harvesting just in case of bark beetle infestation. Wind throw is frequent in the area with single tree events and events affecting larger areas.

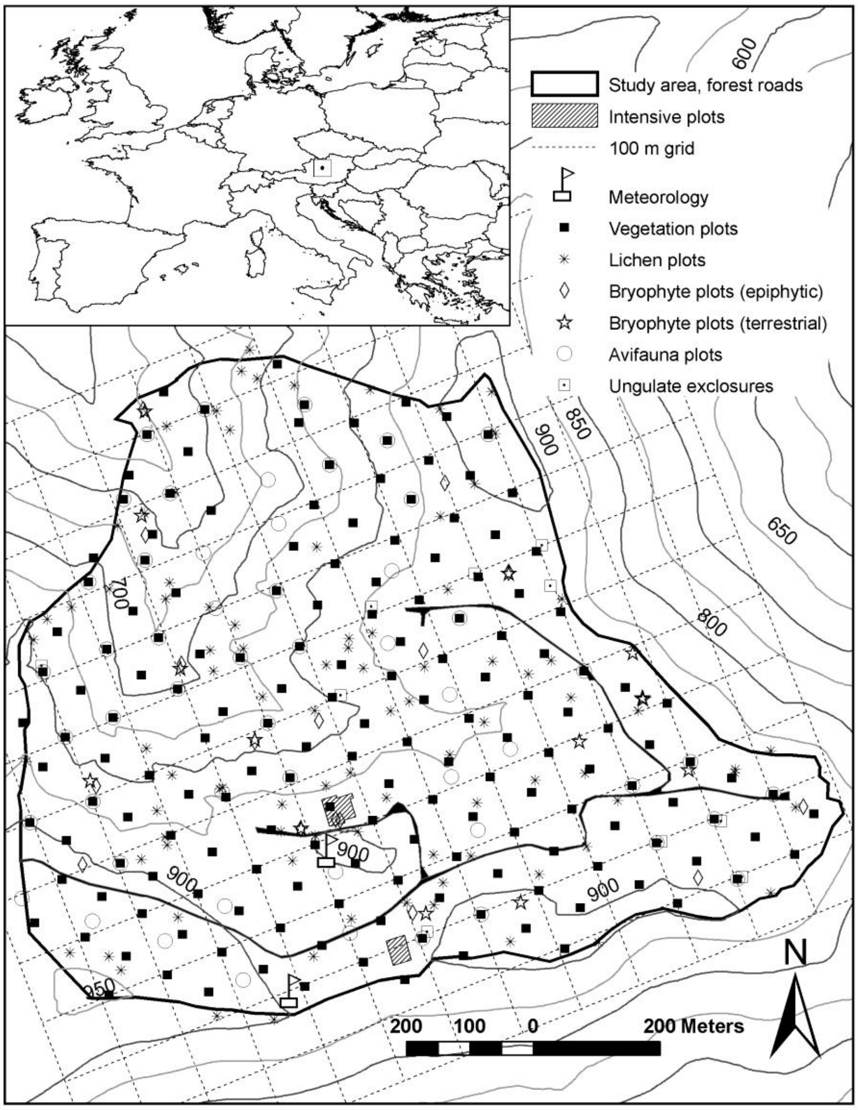

Fig. 1: Location of the IM-site Zöbelboden in Austria and main monitoring infrastructure

Basic information on LTER-Zöbelboden	
coordinates	latitude: 47° 50' 30" / longitude 14° 26' 30"
maximum elevation	950 m.a.s.l
minimum elevation	550 m.a.s.l
province	Upper Austria (Oberösterreich)
district	Steyr
land owner	Federal Forests Austria PLC
size	90 ha
precipitation	1500 - 1800 mm/year
temperature	+ 7.2° C (long-term average)
bedrock	calcitic dolomite (Hauptdolomit)
vegetation period	approx. 190 d/y (>5°C)
anthropogenic stress	forestry (until 1998), hunting, airborn pollution
protection status	Limestone Alps National Park (since 1998)

Main ecosystems

The watershed can be divided into two distinct sites: A very steep (30–70°) slope from 550–850 m a.s.l. and an almost flat plateau (850-956 m.a.s.l.) on the top of the mountain. The areal coverage of each site is 50 % of the watershed. At each site, one plot has been selected for intensive measurements of hydrochemical variables. Intensive plot I (IP I) is located on the plateau where Chromic Cambisols and Hydromorphic Stagnosols are found. Intensive plot II (IP II) is located on the slope and is dominated by Lithic and Rendzic Leptosols (FAO/ISRIC/ISSS, 2006). The mean slopes are 14° at IP I and 36° at IP II. IP I is dominated by Norway spruce (*Picea abies*) following plantation after a clear cut around the year 1910, whereas a mixed mountain forest with beech (*Fagus sylvatica*) as the dominant species, Norway spruce (*Picea abies*), maple (*Acer pseudoplatanus*), and ash (*Fraxinus excelsior*) covers IP II. After wind and bark beetle damage at IP I a third intensive plot (IP III) has been established in the year 2008 representing the plateau ecosystem. IP I is further used for studying the effects of disturbance on these ecosystems.

The table below shows forest and soil characteristics of the two intensive plots (IP I, IP II) characterizing the main ecosystems of LTER Zöbelboden. Soil chemistry is taken from 16 locations (each 4 soil pits) on a 4 x 4 m grid adjacent to the intensive plots in the year 2004. Mean values and standard deviations (in parenthesis) are stated; also [a]Net mineralization ($N_{net\ min}$) and gross consumption ($N_{gross\ cons}$) of ^{15}N labeled NH_4^+ applying pool dilution experiments with 37 (IP I) and 39 (IP II) samples acquired on a 5 x 5 m grid in August in the year 2007 adjacent to the intensive plots are shown.

Description of Intensive Plots			
		IP I	**IP II**
Actual forest type		Spruce dominated forest	Mixed beech, spruce, maple and ash forest
Potential natural vegetation		*Cardamino trifoliae-Fagetum* sensu Willner 2002	*Adenostylo glabrae-Fagetum* sensu Willner 2002
Soil types		Chromic Cambisols and Hydromorphic Stagnosols	Lithic and Rendzic Leptosols
aspect [°]		0-5	25-35
average soil depths [cm]		51	12
pH_{CaCl2}	organic layer	5.3 (0.6)	5.7 (0.4)
	0-10 cm	6.3 (0.6)	6.7 (0.3)
	10-20 cm	6.6 (0.3)	6.9 (0.1)
C_{org} [%]	organic layer	36 (9.2)	44 (6.1)
	0-10 cm	10.1 (3.5)	20.3 (6.6)
	10-20 cm	5.1 (1.6)	12.7 (1.7)
N_{tot} [%]	organic layer	1.3 (0.2)	1.5 (0.2)
	0-10 cm	0.6 (0.2)	1.2 (0.2)
	10-20 cm	0.4 (0.1)	0.8 (0.2)
[a]$N_{net\ min}$ [$mg.kg^{-1}.d^{-1}$]	0-5 cm	-3.2 (5.2); max 5.8; min -26.0	-1.7 (2.1); max 1.8; min -10.9
[a]$N_{gross\ cons}$ [$mg.kg^{-1}.d^{-1}$]	0-5 cm	15.1 (11.0); min -1.9; max 59.5	5.3 (4.4) ; min -1.2; max 23.0

Fig. 2: Intensiv Plot 1 (plateau) and Intensive Plot 2 (slope)

Karst hydrology

Due to the dominating dolomite, the catchment is not as heavily karstified as limestone systems, but shows typical karst features, such as conduits and sink holes. Tracer experiments showed the large heterogeneity of the hydrologic system. At several springs the injected tracer was detected within one day indicating preferential flow. But, reanalysis of some springs in 2009 showed that traces of it could be detected even after ten years indicating the importance of the rock matrix. These results are supported by water age dating with CFCs, ^{3}H and $^{3}H/^{3}He$ resulting in a mean residence time of up to 20 years at spring 501. Damped $\delta^{18}O$ values at some springs indicate a delayed flow component. A water balance applied to the whole system demonstrated that major parts of the rainfall input are transformed into interflow and deep percolation within the dolomite leaving the system as diffuse contribution to the streams and at springs instead of running off superficially. Ongoing monitoring and research is aiming at better describing and modeling the hydrology of the catchment.

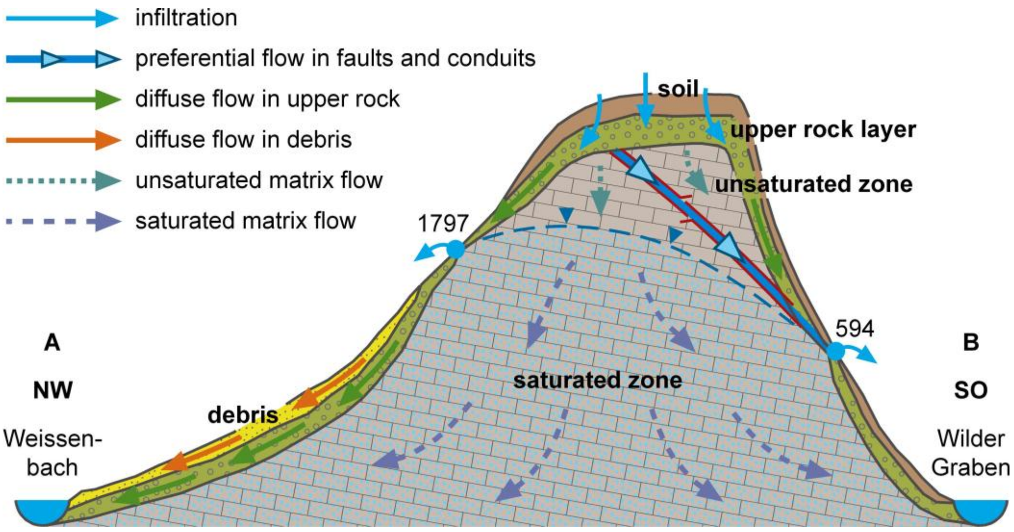

Fig. 3: Schematic cross section of the site from northwest to southeast intersecting the measuring weir (from Hartmann et al. 2010)

Fig. 4: Measuring weir at the catchment runoff

Biodiversity

Forest floor vegetation, epiphytic lichens and bryophytes on tree trunks, forest floor bryophytes and birds are monitored using permanent plots distributed over the entire area. More intensive and small scale monitoring of forest floor vegetations dynamics is carried out at the intensive plots.

Biodiversity monitoring (catchment scale)																					
year of survey	1991 - 1999									2000 - 2011											
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	10	11
forest tree inventory		■													■					■	
forest floor vegetation		■	■												■					■	
terrestrial and epiphytic bryophytes		■	■					■						■	■					■	
epiphytic lichens			■						■						■					■	
birds							■								■						

Fig. 5: Biodiversity monitoring in the forest floor (left) and with lichens on tree trunks (right)

Appendix

Overview of measured parameters

Measured parameters				
ITEM	Further specification	Method	Sampling frequency	Size of plot
Meteorological measurements on the site				
PAR		see ICP IM manual	half hour	
Wind direction (mean and gust)		see ICP IM manual	half hour	
Wind speed (mean and gust)		see ICP IM manual	half hour	
Air humidity		see ICP IM manual	half hour	
Air temperature	standard and above forest canopy	see ICP IM manual	half hour	
Precipitation		see ICP IM manual	half hour	
Rainfall Chemical analysis (NO_2^-, NO_3^-, NH_4^+, DOC…)	also, fog, snow; wet-only, dry, bulk deposition, stemflow, throughfall		daily to monthly	
Global radiation		see ICP IM manual	half hour	
Reflected global radiation		see ICP IM manual	half hour	
Sky temperature		see ICP IM manual	half hour	
Ground temperature		see ICP IM manual	half hour	
Albedo		see ICP IM manual	half hour	
Net sol radiation		see ICP IM manual	half hour	
Net far radiation		see ICP IM manual	half hour	
Net radiation		see ICP IM manual	half hour	
Diffuse sol radiation		see ICP IM manual	half hour	
Sunshine duration		see ICP IM manual	half hour	
Heat flux		see ICP IM manual	half hour	
Temperature soil at 5cm		see ICP IM manual	half hour	
Atmospheric pressure		see ICP IM manual	half hour	
Wet/Dry Deposition Collector		see ICP IM manual	half hour	
UV radiation		see ICP IM manual	half hour	
Others, please specify				
Soil properties				
Type	point data, map	see ICP IM manual		
Texture	from approx. 80 positions	see ICP IM manual		
Depth	from approx. 80 positions	see ICP IM manual		
Hydraulic conductivity (Ks)	selected samples	see ICP IM manual		
Unsaturated hydraulic conductivity, Pf curve	selected samples	see ICP IM manual		
Soil chemical characteristics (pH, CEC, EC, C and N content, …)	selected samples	see ICP IM manual		
Soil bulk density	selected samples	see ICP IM manual		
Soil contamination (N deposition, ash deposition, heavy metal, …, specify)	selected samples	see ICP IM manual		
Soil enzymes	once within a project			

Soil array measurement:				
Soil moisture with depth	TDR equipment at three intensive forest plots	TDR	10 minutes	three intensive plots
Soil temperature with depth	at three intensive forest plots and in a clearing area	soil temperature sensors	10 minutes	three intensive plots
CO_2 surface flux	since 2009 in two forest plots including specific measurements on heterotrophic respiration	portable equipment	monthly	three intensive plots
Soil solution sampling and measurements: DOC, DON, P, K, Ca, Mg, Na, Cl…(specify)	all elements, including heavy metals	see ICP IM manual	biweekly to monthly	three intensive plots
Groundwater temperature	measuring weir		10 minutes	three intensive plots
Groundwater chemistry: DOC, DON, P, K, Ca, Mg, Na, Cl…(specify)	all elements, including heavy metals	see ICP IM manual	half hour	three intensive plots
Local atmosphere				
Ozone	EMEP air quality station		half hour	clearing area
Aerosols	EMEP air quality station		daily	clearing area
Humidity		see ICP IM manual	half hour	clearing area
N-deposition, dry		see ICP IM manual	biweekly to monthly	clearing area
N-deposition, wet		see ICP IM manual	biweekly to monthly	clearing area
CH_4 flux	EMEP air quality station		half hour	clearing area
Temperature		see ICP IM manual		clearing area
Global radiation		see ICP IM manual		clearing area
PAR	also hemiphotographs	see ICP IM manual		clearing area
CO2	forest soil		monthly	
18O/16O	precipitation, runoff			
H_2O flux	water flux model for 2 intensive plots and the entire catchment		daily	
Hydrological characterics				
discharge, catchment	measuring weirs, hydrological catchment model		daily	
drainage	seepage from soils (three intensive plots), TDR Measurements and model (Brook90)		daily	
runoff, local/plot	seepage from soils (three intensive plots), TDR Measurements and model (Brook90)		daily	

soil water quality	continous monitoring at three intensive plots with lysimeters (all elements)	Plate-Lysimeters	biweekly to monthly	three intensive plots with each 1 ha
groundwater quality	continous monitoring at one (two) weirs of all elements		weekly	
Autotrophic compartment				
Abundance	trees, vascular plants, lichens, bryophytes	permanent plots	several years	0.1 to 100 m²
Biomass	tree species	permanent plots, forest inventory	several years	100 m²
Biodiversity	trees, vascular plants, lichens, bryophytes	permanent plots	several years	0.1 to 100 m²
Production	tree species	permanent plots, forest inventory	several years	100 m²
Root biomass	from tree biometry data	soil inventories on 65 permanent plots	several years	100 m²
Specific measurements on specific species (for example Oak water potential …)	N uptake in the canopy of beech and spruce by 15N experiments		several years	100 m²
LAI		several methods	several years	100 m²
C, N, Mg, K, P, Na, content...	spruce needle and beech leafs, all elements	continuous measurements on approx. 30 trees	annual	100 m²
Biodiversity:				
Vascular plants	forest floor	intensive plots, permanent plots	several years	0.25 to 100 m²
Lichens	epiphytic lichens on tree trunks	approx 80 trees	several years	0.1 m²
Mosses	epiphtic bryophytes on tree trunks and bryophytes on forest floor	approx 40 permanent plots	several years	1 m²
Mammals: small mammals	one study concerning tree dynamics and browsing of mice		several years	100 m²
Mammals: ungulates	exclosures and control plots	10 permanent pairs of plots	several years	100 m²
Birds	breeding birds	50 permanent plots	several years	100 m²
Fish	one record in the small river at the bottom of the catchment		several years	

Selected publications

Hartmann, A., Kralik, M., Humer, F., Lange, J. and Weiler, M., 2011. Identification of a karst system's intrinsic hydrodynamic parameters: upscaling from single springs to the whole aquifer. Environmental Earth Sciences: [DOI 10.1007/s12665-011-1033-9].

Jost, G., Dirnböck, T., Grabner, M.-T. & Mirtl, M. 2011. Nitrogen leaching of two forest ecosystems in a Karst watershed. Water Air and Soil Pollution 218: 633–649.

Pröll G., Dullinger S., Dirnböck T., Kaiser C. & Richter A. 2011. Effects of nitrogen on tree recruitment in a temperate montane forest as analysed by measured variables and Ellenberg indicator values. Preslia 83(1): 111–127.

Diwold, K., Dullinger, S., Dirnböck, T. 2010. Effect of nitrogen availability on forest understorey cover and its consequences for tree regeneration in the Austrian limestone Alps - Plant Ecology 209: 11-22.

Kobler, J., Fitz, J.F., Dirnböck, T., Mirtl, M. 2010. Soil type affects migration pattern of airborne Pb and Cd under a spruce-beech forest of the UN-ECE Integrated Monitoring site Zöbelboden, Austria. Environmental Pollution 158: 849-854.

Dirnböck, T., Mirtl, M. 2009: Integrated monitoring of the effects of airborne nitrogen and sulfur in the Austrian Limestone Alps. Is species diversity a reliable indicator? – Mountain Research and Development 29: 153-160. [http://dx.doi.org/doi:10.1659/mrd.1072]

Umweltbundesamt 2009. Long-term deposition of trace metals at the Integrated Monitoring site Zöbelboden, element concentrations and loads between 1994 and 2008. Report 0246, Umweltbundesamt GmbH, Vienna, Austria.

Hülber, K., Dirnböck, T., Kleinbauer, I., Willner, W., Dullinger, S., Karrer, G., Mirtl, M. 2008. Long-term impacts of nitrogen and sulphur deposition on forest floor vegetation in the Northern limestone Alps, Austria. Applied Vegetation Science 11: 395-404.

Zechmeister, H.G., Dirnböck, T., Hülber, K., Mirtl, M. 2007. Assessing airborne pollution effects on bryophytes - Lessons learned through long-term integrated monitoring in Austria. - Environmental Pollution 147: 696-705.

Umweltbundesamt 2007. Effects of Nitrogen and Sulphur deposition on forests and forest biodiversity. Austrian Integrated Monitoring Zöbelboden. Report 0077, Umweltbundesamt GmbH, Vienna, Austria.

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