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Summaries of diploma and PhD theses (1995)

Diploma theses (10)

Small-scale use of vegetation by red deer (*Cervus elaphus* L.) on two subalpine grasslands in the Swiss National Park

Kleinräumige Nutzung von zwei subalpinen Rasen durch Rothirsche (Cervus elaphus L.) im Schweizerischen Nationalpark; 47 pp.

GÉRALD ACHERMANN

On two subalpine grasslands in the Swiss National Park the produced and consumed phytomass by red deer (*Cervus elaphus* L.) was studied during three periods from May to August in 1995. On "Il Fuorn" (*Trisetetum flavescens*; 1790 m a.s.l.; 3.7 ha) and "Stabelchod" (combination of *Crepido-Festucetum nigrescens*, *Seslerio-Caricetum sempervirentis* and *Medicagini-Mesobrometum raeticum*; 1900 m a.s.l.; 2.6 ha; $N = 15$) a paired-sample design was used; grazed and ungrazed plots (0.25 m²) formed paired samples. The grassland of Il Fuorn was subdivided in a facies A (without litter) and a facies B (feltlike litter). At the end of each period, the phytomass of the ungrazed and grazed plots was cut 1.5 cm above ground and crude protein and crude fibre content of the clipped and dried material were analysed. For the next period, new sampling plots were chosen.

- Both sites were almost exclusively used by hinds and calves. Average densities of red deer were 8–14 on Il Fuorn and 1–4 individuals ha⁻¹ on Stabelchod per night.
- On Il Fuorn, facies A was characterized by *Festuca rubra*, *Trifolium repens* and *Veronica serpyllifolia*. Facies B was characterized by *Dactylis glomerata*, *Poa angustifolia*, *Pimpinella major*, *Rumex alpestris* and *Carum carvi*.
- On Il Fuorn the dry weight (DW) of phytomass was for all periods significantly smaller on grazed plots of facies A (without litter) than on ungrazed plots ($P < 0.05$; Wilcoxon-Test). During the first period (5.5.–10.6.) 2.2, during the second period (10.6.–4.7.) 2.6 and during the third period (5.7.–28.7.) 3.2 g DW m⁻² d⁻¹ were produced and 1.9, 2.2 and 2.2 g DW m⁻² d⁻¹ were consumed by red deer. On facies B 10.4, 4.8 and 5.9 g DW m⁻² d⁻¹ were produced and 5.3, 0.7 and 3.2 g DW m⁻² d⁻¹ were consumed.
- On Stabelchod the phytomass was only after the first period significantly smaller on the grazed than on the ungrazed plots ($P < 0.002$; Wilcoxon-Test). During the first period (10.5.–22.6.) the rate of production was 1.3 g DW m⁻² d⁻¹, during the second period (22.6.–19.7.) 2.1 and during the third period (20.7.–11.8.) 0.5 g DW m⁻² d⁻¹. The corresponding rates of consumption were 0.6, 0.3 and 0.2 g DW m⁻² d⁻¹.
- On facies A of Il Fuorn the crude fibre content of graminoids increased from 200 to 250 g kg⁻¹, on facies B the crude fibre content increased from 250 to 300 g kg⁻¹. The crude protein content of forbs on facies A remained by 250 g kg⁻¹ during all periods, whereas on facies B the crude protein content of forbs decreased from 230

to 160 g kg⁻¹. The steady grazing on facies A during the vegetation period resulted for grasses and forbs in a much smaller increase of crude fibre and a smaller decrease of crude protein content compared to facies B, leading to a positive feedback between red deer grazing and herbage quality.

6. On Stabelchod the crude fibre content of graminoids increased from 225 to 275 g kg⁻¹ whereas the crude protein content of forbs decreased from 200 to 150 g kg⁻¹.

The results show the different significance of the two subalpine grasslands as a food resource for hinds. Not only differed the rate of consumption on the two subalpine grasslands, but also the rate of consumption was different on facies A and facies B. Especially the productive grassland of Il Fuorn was responsible for the concentration of hinds on this area by producing a large amount of qualitatively good food, whereas the less productive grassland of Stabelchod was extensively used by red deer.

Growth parameters and biomass turnover in relation to the ecological behaviour of two annual species

Wachstumsparameter und Biomasseturnover in bezug auf die ökologischen Ansprüche zweier annualer Arten; 45 pp.

AGATA DE GIORGI

Species from unproductive habitats usually have slow biomass turnover linked with low maximal relative growth rate (*RGR*). Constraints caused by tissue density link these two parameters together. High tissue density, which is necessary for a long organ life span, prevents fast resource acquisition and fast growth. These relationships between growth rate, organ life span and tissue density have been found in perennial grasses. The question is, whether it can also be found among ecologically contrasting annual species, as annuals are by definition short-lived.

Two congeneric species were studied: *Galeopsis angustifolia*, characteristic of sunny, dry habitats of low productivity, and *G. tetrahit*, characteristic of fertile and often shady habitats. Relative growth rate, leaf life span, root mortality, growth parameters and reproduction of the two contrasting species were studied. The fresh weight to dry weight ratio, which reflects composition and anatomy of the organs, was determined.

1. Relative growth rate of both species increased with increasing nutrient availability. No significant interspecific differences in *RGR* were found.
2. There were hardly any interspecific differences in leaf life span before onset of flowering. Only on nutrient-rich soil the leaves of *G. angustifolia* had a shorter life span. There were no significant differences in root mortality after 111 days.
3. Tissue density of both species responded to nutrient availability. *G. angustifolia* had a higher leaf tissue density. No interspecific differences in root tissue density were found.
4. *G. tetrahit* had a higher leaf area ratio (leaf area per plant dry weight) than *G. angustifolia*. *G. angustifolia* had a higher root length ratio (root length per plant dry weight).
5. Differences in leaf area ratio and root length ratio were best explained by differences in thickness of leaves and roots: *G.*

tetrahit had thinner leaves and *G. angustifolia* had thinner roots.

6. *G. angustifolia* produced on all three nutrient levels more flowers, and it flowered over a longer period. The number of flowers of both species increased with increasing nutrient availability.
7. *G. tetrahit* had larger seeds than *G. angustifolia*.

In contrast to many perennials, ecological differences between two congeneric annuals in relation to productivity of the characteristic habitat are not associated with differences in *RGR* and leaf life span. Thickness of leaves and roots, and seed size were the parameters with the most distinguished differences between these two annual species.

Plant development in ecologically restored plots in machine-graded ski runs above timberline

Pflanzenentwicklung in standortgerecht renaturierten Skipistenflächen oberhalb der Waldgrenze; 64 pp.

RALPH ETTER

The study deals with ecologically restored plots in machine-graded alpine ski runs (2350 m a. s. l.) in the surroundings of Davos, Grisons. It includes both research on plant demography and some sociological/educational aspects. The development of the plant cover five years after restoration was assessed with demographic methods focusing on plant species richness (α -diversity) and frequency of various age-state classes (δ -diversity). The plots on the ski run were restored in a *pro juventute* action with teenage volunteers and their teacher; the study included accordingly an assessment of value of restoration work as a form of environmental education.

The total number of plants in restored plots was significantly higher than that in the controls. Restored plots were also characterized by a higher number of species and plant families.

In addition to global assessment of plant communities in the restored plots, populations of three species were studied separately. *Trifolium thalii* represented transplants intro-

duced into the restoration plots, whereas *Gnaphalium supinum* and *Silene rupestris* immigrated spontaneously. *Trifolium thalii* characterized by exceedingly high survival and reproduction rates proved to be a good species for restoration. Spatial structure and distribution of age-state classes in *Gnaphalium supinum* corresponded to that of a pioneer species, whereas the demographic behaviour of *Silene rupestris* did not permit to recognize any clear trends. The strongly varying pattern of small-scale distribution of species and age-state variants in the studied plots was clearly influenced by the pronounced heterogeneity of high-alpine sites.

An interview with the teacher of the school class who did the restoration work, helped to assess the educational value of the action. The subsequent assessment of the interview included a study of literature on the subject. Following these criteria, the restoration of alpine ski runs by teenage volunteers was assessed as a valuable form of environmental education fulfilling the didactic and pedagogic objectives.

The effects of Scottish highland cattle on a montane pasture

Einfluss von Schottischen Hochlandrindern auf eine montane Weide im Oberen Tösstal; 80 pp.

STEFAN ERZINGER

Grazing management has a big impact on the vegetation of pastures. Changes in animal species or breed, and in time or intensity of use of a pasture will lead to vegetation change.

The diploma thesis investigates the effects of a change in grazing system (continuous grazing by Scottish Highland Cattle instead of rotational grazing by Swiss Brown Cattle) upon the vegetation of a Montane pasture (2.5 ha; mostly Cynosurion) at the Toesstal (Kanton Zurich, Switzerland).

One year after the grazing system was altered, no effect upon the number of plant species and species cover was found. The use of habitat by Highland Cattle is not random. Different parts of the pasture are preferred for different activities such as feeding, resting,

ruminating and excretion. A comparison of food selection (based on determination of cuticular fragments in dung) by Highland Cattle and Brown Cattle showed no difference between the two breeds.

The results indicate that changes in the vegetation of a fairly good pasture because of a change in cattle breed are not expected to be severe. The question, whether the change from rotational to continuous grazing has an effect on vegetation, cannot be answered from this study. However, as long as intensity of usage does not increase, no negative effects are expected. In predicting the effects of grazing, the choice of the animal breed seems to be less important than time and intensity of grazing.

Vegetation of woodlands on old landslides at the Rossberg (SZ)

Vegetation in Blockschuttwäldern am Rossberg (SZ); 100 pp.

DIETER GILLMANN

On the "Rossberg" (SZ) various bigger and smaller landslides occur caused by geological circumstances. Therefore, we can find block debris not only near the famous area of the "Goldauer Bergsturz" of 1806, but also east and west of the main direction of this slide.

The diploma thesis investigates the vegetation of three forest stands on old block debris which were not affected by the above mentioned landslide of 1806. The vegetation was analysed in three microhabitats: flat areas, moderately tilted block surfaces, and steep block flanks.

The plant communities of the flat areas were classified as Pulmonario- and Cardamino-Fagetum. Additionally, the following communities were recorded: Galio odorati-Fagetum in a typical and a base-rich variant, Aro-Fagetum, Luzulo silvaticae-Fagetum, Phyllitido-Aceretum and Asperulo taurinae-Tilietum. The succession on the areas studied has probably reached a final stage. However, the block debris provides a high diversity of habitats.

The Pulmonario- and Cardamino Fagetum usually grow on skeleton-rich brown soil or regosols, the Galio odorati-Fagetum on

deeper brown soil. The soil of the Aro-Fagetum contained a higher amount of clay. The *Luzulo silvaticae*-Fagetum was found on acidic dry brown soil, *Phyllitido-Aceretum* and *Asperula taurinae*-Tiliatum on regosols or pararendzina.

The block flanks were covered by two moss communities: *Thamnetum alopecuri* and *Neckero-Anomodontetum viticulosi*; the *Neckero-Anomodontetum* occurred in several variants. Field experiments revealed that the habitat of the *Thamnetum alopecuri* was

more humid than that of the *Anomodontetum*. The rich vegetation of the block flanks was similar to the herb layer of the *Phyllitido-Aceretum*.

The vegetation of the block surfaces and the surrounding flat areas were clearly different. Several herb, shrub and tree species which were abundant on all flat areas were missing on the block surfaces. On the other hand, some species were more frequent on the blocks.

Zinc, copper and cadmium tolerance and cotolerance in *Bromus erectus*, *Festuca rubra* cv. Merlin and *Festuca rubra trichophylla*

Toleranz und Kotoleranz gegenüber Zink, Kupfer und Kadmium bei Bromus erectus, Festuca rubra cv. Merlin und Festuca rubra trichophylla; 37 pp.

MARTIN HERMANN & LORENZO SONOGNINI

The topic of this diploma project is heavy-metal tolerance and cotolerance in plants. Most tolerant plants are derived from heavy-metal contaminated areas and often show only tolerance to the particular metals present at high levels. Tolerance to metals not present in the origin area is defined as cotolerance.

This study investigates, whether plants selected for one or two specific heavy-metal tolerances show cotolerance to further metals. Two approaches were used to answer this question. Firstly, zinc and cadmium tolerance and copper cotolerance of the zinc/lead-tolerant ecotype *Festuca rubra* cv. Merlin were investigated. Secondly, an attempt was made to select copper- and zinc-tolerant individuals from non-tolerant populations of *Bromus erectus* and *Festuca rubra trichophylla*. The selection took place by germinating and growing plants in soil contaminated with heavy-metals. After the selection-process,

tolerance and cotolerance were quantified using different tolerance-indices.

The experiments revealed a clear zinc and cadmium tolerance in *F. rubra* cv. Merlin. Copper cotolerance could not be confirmed. Significant copper and zinc tolerance was shown in individuals of *B. erectus* which had been selected for tolerance to these metals. Furthermore the investigations revealed a clear zinc cotolerance in copper-selected plants of *B. erectus*.

Investigations into the altitudinal gradient of forest communities in the lower part of the landslide at Goldau

Pflanzensoziologisch-standortkundliche Untersuchungen auf Höhengradienten im unteren Teil des Sturzhangs im Goldauer Bergsturz; 53 pp.

JOST MATTLI

The site where the landslide at Goldau took place in 1806 is now again covered by forest of different associations. The forest communities change with increasing height above sea-level: in the lower part there is a mosaic of deciduous forest associations, above those is a Piceo-Fagetum followed by a Piceetum, and on the top occurs a Pinetum, which becomes thinner and thinner with increasing height above sea-level. However, in some places the vegetation differs from this pattern, since the borders of the associations are more irregular, e.g. sometimes the beech grows at an altitude typical for the pine and *vice versa*.

It would be plausible that the mosaic of forest associations is due to one or more soil factors. To test this hypothesis vegetation and soil have been investigated for ten sample plots on each of four transects. A floristic classification differentiated the sample plots into three types. These types have been correlated with soil factors, but the differences between the types were not significant. In contradiction to the literature both, beech and pine, grew on shallow as well as on deep soils.

Endomycorrhiza of grasses important in restoration ecology in their natural habitats above timberline

Endomykorrhiza von renaturierungsökologisch bedeutenden Gräsern an ihren natürlichen Standorten oberhalb der Waldgrenze; 61 pp.

ROCHUS SCHERTLER

In alpine grassland above timberline (at Jakobshorn, Davos) the endomycorrhiza on roots of the two grass species *Helictotrichon versicolor* (Vill.) Pilger and *Deschampsia flexuosa* (L.) Trin, important in restoration ecology, have been investigated. The infections mainly consisted of arbuscular mycorrhizae (AM) and root-endophytes with dark-septate hyphae, which were previously reported to be associated to this alpine ecosystem.

Infection-intensity was determined with a new counting method. Based upon percentage of infected root sectors and the average occurrence of fungal structures per root diameter for both infection types in the roots of both grasses DS-mycelium was successfully isolated and grown in pure culture.

In the research area three transects, separated into eight plots (1.5 m x 1.5 m) with both grass species present, were established along an altitude gradient (2370–2570 m

a. s. l.). In every sector the ecological indicator values after Landolt were determined. At the beginning of August and October root samples were collected from each plot, and the intensities of the various infections were determined.

All root samples always showed both infection types. The average value for AM for *Helictotrichon versicolor* at the beginning of August was 79% infected root sectors and 3.9 AM structures per root diameter; for *Deschampsia flexuosa* it was 61% and 3.6. The values of *Helictotrichon versicolor* at the beginning of October were 87% and 4.7. The average values for the DS-infection of *Helictotrichon versicolor* at the beginning of August were 78% infected root sectors, and 5.3 DS-structures per root diameter, for *Deschampsia flexuosa* it was 82% and 6.4.

The values of *Helictotrichon versicolor* at the beginning of October were 93% and 10.6.

One of the DS-endophytes was identified as *Cryptosporiopsis radicola* Kowalski & Bartnik (Coelomycetes); another mycelium can be classified as a species of either *Phialophora* Cain or *Rhizoctonia* Peyronel (Ascomycetes).

The different methods of quantifying root infections, the influence of ecological parameters on endomycorrhiza of the investigated grasses and the use of AM inoculum for restoration of disturbed sites along skiruns are discussed.

In an appendix data about the influence of CO₂-application on the endomycorrhiza of *Carex curvula* in an alpine Caricetum *curvulae* (Furkapass, Wallis) are presented.

Distribution and limits of evergreen broad-leaved plants in the southern Ticino

Ausbreitung und Grenzen laurophyller Arten im Südtessin; 37 pp.

GIAN-RETO WALTHER

Evergreen broad-leaved plant species are sensitive to drought and temperatures below -5–10 °C. Their rather large, stiff and loriate leaves are mostly unhairy and dark-green. These species occur originally in evergreen broad-leaved forests. They occur all over the world in the warmer zones, from the warm-temperate zone where they form the climax, to the drier (sub-)tropical high mountains where they may grow in the montane belt. Ecologically they are situated between the rainforest and the sclerophyll forests or deciduous forests. Evergreen broad-leaved forests occur in Japan, China, parts of the USA, South-America, South-Africa, Australia and New Zealand, but also in Europe

(Portugal, Canaries, Turkey and parts of Ex-Yugoslavia). In Switzerland laurophyllous species have been planted as ornamental plants. Recently they started colonizing mesic forests adjacent to gardens in the warmest parts of southern Switzerland. Such areas were investigated in the diploma thesis.

The study area was a south-facing slope along Lake Maggiore up to the village of Tenero, and further along the Magadino plain right up to Bellinzona. The aim was to determine the distribution and the limits of evergreen broad-leaved plants in the southern Ticino by gradients in altitude and in continentality. In the area influenced by the lake, the process of invasion of evergreen exotic

plants is advanced compared with the more continental part of the study area. In climatic especially favourable sites under the influence of the lake, evergreen broad-leaved species are already part of the tree layer; and in several places species like *Eleagnus pungens*, *Lonicera japonica*, *Prunus laurocerasus* and *Laurus nobilis* but also the palm *Trachycarpus fortunei* dominate the understorey. Recruitment of evergreen exotics is successful up to about 600 m a.s.l.

In addition, the vegetation of the smaller of the two islands of Brissago, San Apollinare, was investigated. Apart from numerous native species, there are also some representatives of foreign regions growing on this island. On the southern end, *Acacia dealbata*, originally occurring in Southeast Australia, established as a bushy group. Furthermore

there are several evergreen broad-leaved species growing on the island. Their reproduction has been favoured by the particularly mild climatic conditions on this island. In addition to these species, on the south slope *Pittosporum tobira*, a native of East Asia, was found.

In terms of nature conservation this island holds a special position. Within its embankment several rare plant species occur that are classified as endangered or vulnerable (*Littorella uniflora*, *Allium angulosum*, *Gratiola officinalis* and *Sagina apetala*). In addition there are three other species of the list of threatened species within Switzerland: *Cyperus glomeratus*, *Orobranche* cf. *hederae* and *Vinca major*. San Apollinare is the only island in Lake Maggiore carrying mostly native vegetation.

Effects of "Buntbrachen" on territoriality, breeding biology and diet of the skylark *Alauda arvensis*

Auswirkungen von Buntbrachen auf die Territorialität, Brutbiologie und Nahrungsökologie der Feldlerche Alauda arvensis; 38 pp.

URS WEIBEL

A population of skylarks *Alauda arvensis* were studied during one breeding period in 1995 in the Klettgau (Kanton Schaffhausen, Swiss lowlands). The study area is intensively farmed and comprises about 500 ha. Agricultural land use is dominated by winter cereal farming (wheat, barley). Since 1991 the habitat quality has been improved with a network of wild flower strips ("Buntbrachen"). The aim of the study was to monitor the beneficial effect of wild flower strips on the breeding biology, the territoriality and the diet of skylarks. Wild flower strips 5–10 m wide were mainly sown with a locally produced seed mixture. They made up 1% of the farmed area.

Mean territory size is 1.3 ha ($N = 137$), which is low for skylarks. This is mainly an effect of the small field size in the study area. Territory size decreased with increasing share of "Buntbrache", but no statistically significant difference in territory size was found between territories which had "Buntbrache" and those which had none. This is probably due to the relatively small proportion of "Buntbrache" in most territories of skylarks.

Seasonal distribution of clutches in 1995 differed significantly from the cumulated clutch distribution from 1991–1994. Differences were caused by climatic factors (temperature, rainfall). Seasonal clutch distribu-

tion showed two peaks which corresponded to the natural reproduction cycle. The relatively high crop diversity, an effect of the small fields, offered suitable nesting sites for the skylarks. "Buntbrachen" are used for nesting mostly in May and June. "Buntbrachen" had about six times more nests than expected from a random distribution.

Mean clutch size was smaller than values cited in the literature. The characteristic seasonal differences in clutch size can be confirmed. Territories with a share of "Buntbrachen" have larger clutch size from April to June than territories without "Buntbrachen".

Mean breeding success was 50%, and predation was responsible for 65% of the egg losses and 67% of the chick losses. Breeding success, as well as predation rate, is crop-dependent and differs during the breeding season. There was a high tendency for low breeding success within a distance of 5 m to a path, but this result was statistically not significant.

No differences in nestling growth (weight, wing feather length) between territories with and without "Buntbrachen" could be detected, perhaps because of the small data set. Nestling weight of early broods was lower compared with late broods. An insufficient

food availability in the intensively cultivated crops early in the breeding season could be the reason for this result.

"Buntbrachen" were highly preferred as foraging sites early in the breeding season (April/May) which seems to indicate good food availability. Other attractive foraging targets are set-asides (ryegrass-clover mixture), grassy margins along paths, stubble-fields, sugar-beets and maize. No sex specific differences in foraging behaviour in regard to feeding frequency and crop specific foraging sites were found.

Data of nestling diet collected with the ligature method show a dominance of Diptera and Araneae.

The results of this study demonstrate the beneficial effect of "Buntbrachen" for skylarks. "Buntbrachen" increase the structural diversity of the habitat and offer good nesting and foraging sites. To enable good locomotion on the ground, "Buntbrachen" have to provide high heterogeneity in vegetation height, structure and biodiversity. Tall dense vegetation limits their ecological benefit for skylarks. In order to minimise predation, "Buntbrachen" should be closed at the exposed sides with a strip of crop similar to that of the adjacent field.

PhD theses (3)

Transition zone from beech to spruce forest in the Northern Swiss Alps – climatic, edaphic and vegetational aspects

Die Übergangszone von Buchen- und Fichtenwald in den nördlichen Kalkalpen – klimatische, edaphische und vegetationskundliche Aspekte
Dissertationes Botanicae, **255**, 1–272 (1995)

MONIKA ADAM

In the oceanic and suboceanic Northern Alps of Switzerland, the timber line is generally formed of spruce (*Picea abies* (L.) Karst.),

but also occasionally of beech (*Fagus sylvatica* L.). The lower limit of the subalpine spruce forest is frequently formed by the

“Abieti-Fagetum / Veronico latifoliae-Piceetum” ecotone or by the Abietetum which comes between mixed beech forests and spruce forests. The floristic characterization of the ecotone forest communities on carbonate-rich material is difficult. The taxonomic classifications are based on groups of differentiating species (which indicate climatic and edaphic differences), and on the abundance of beech, silver fir (*Abies alba* Mill.) and spruce. Furthermore, with increasing altitude beech becomes dependent on limestone or other carbonate-rich material. This can lead to big differences in the altitudinal upper limit of beech within a small spatial area. The possible causes of differences in the beech upper limit have been studied at three sites in the Tamina and Calfeisen valleys by undertaking climatic, edaphic and phytosociological analyses (beech upper limit in the Tamina and Calfeisen valleys: Großalpwald, 1600 m; Ragolerwald, 1300 m; Calfeisen valley, 1300 m).

Results of the climatic studies

In the Swiss Alps four temperature zones have been ascertained between 800 and 2600 m:

- ground inversion zone: up to c. 1000 m (temperature gradient: $-0.37^{\circ}/100$ m);
- thermal belt (zone): c. 1000–1300 m (temperature gradient: $-0.15^{\circ}/100$ m);
- transition zone: c. 1300–1700 m (temperature gradient: $-0.53^{\circ}/100$ m);
- atmospheric air stream zone: above c. 1700 m (temperature gradient: $-0.48/100$ m).

In Großalpwald, Ragolerwald and Calfeisen valley these temperature zones are characterized by:

- the discontinuous altitudinal gradients of the air and soil temperature;
- the ranges of soil temperature in the main root space of trees;

- the abrupt decrease in the number of days with an air temperature $T \geq 20^{\circ}\text{C}$ and of the cumulative temperature with $T \geq 20^{\circ}\text{C}$ above 1300 m ($T \geq 20^{\circ}\text{C}$ in June and July is important for the development of the beech flower buds);
- the occurrence of frosts with $T < -1^{\circ}\text{C}$ during the vegetation period above 1300 m (frosts in June and July are most damaging to the beech flower buds);
- the larger fluctuations of the curve of the cumulative temperature in forest stands and gaps between 1300 and 1600 m;
- the amplitude of the monthly deviations in soil temperature differences of stands and gaps belonging to the same altitudinal level;
- the “Andauer”-groups of the soil temperature;
- the weather dependent temperature changes in the ranges $[5-10^{\circ}\text{C}]$ and $[10-15^{\circ}\text{C}]$ relative to the entire temperature spectrum in the main root space (i.e. relative temperature fluctuation potential).

The discontinuous temperature gradient of air and soil temperature is modified by the interaction of thermal continentality, “quasi-continentality” of the soil, foehn and soil physical properties.

The influence of thermal continentality is mainly at altitudes above 1300 m. In the research area a distinction has to be made between thermal continentality being conditioned by foehn at Großalpwald, and “true” thermal continentality at Calfeisen valley. Similar to “true” thermal continental conditions foehns induce a rapid increase in temperature during the spring. However, unlike “true” thermal continental conditions these high temperatures extend to the autumn period.

When “quasi-continental” conditions in soil occur, the temperature fluctuations at different soil levels and the hindrance of heat

transfer by thermal conduction is minimal when the weather is warm and dry. However, these effects can be much stronger when the weather is moist and cold. For “quasi-oceanic” conditions the reverse relationships are true.

In the climatic “transition zone”, the soil temperature at the main root space experiences large fluctuations due to strong radiation, foehn and drought effects, which have an influence on the “Andauer” of the soil temperature, the relative fluctuation potential and the soil thermal conductivity.

The thermal factors such as cumulative temperature, thermal continentality and July-temperature cannot explain the local absence of beech at altitudes higher than 1300 m in Ragolerwald and Calfeisen valley.

Results of the edaphic studies

The soils in Ragolerwald may be classified as Eutric Cambisols below 1300 m, and Gleyic and Gleyic-dystric Cambisols above 1300 m. In Großalpwald, Rendzinas (especially in gaps) as well as Eutric and Calcaric Cambisols are common. The soil profile in Sardonawald (Calfeisen valley) is that of Gleyic Podzol.

At all altitudes in Ragolerwald the humus form is “typical mull”. In Großalpwald “moric mull” and “typical mor” are developed in stands, whereas “typical mull” is present in gaps. In Sardonawald a “rawhumus” is present. A_{hh} -horizons (calcium humates) have only developed in the montane belt of Großalpwald below 1600 m.

In Großalpwald (especially above 1600 m) as well as in Ragolerwald (above 1300 m) the clayey proportion in the A-B-C-profile increases with increasing soil depth and altitude. In the gaps clayey soil texture occurs more regularly than in stands.

Coal specimens found in the A- and B-horizons in Großalpwald originate from charcoal-burning.

In Großalpwald all pH-profiles of the mineral soils in stands and gaps are in the carbonate buffer range. In Ragolerwald the A-horizons below 1300 m are in the carbonate buffer range; above 1300 m buffering by variable chemical loading and silicate occurs down to 40 cm soil depth. Beyond 40 cm the carbonate buffer is effective. In Sardonawald, the buffering by aluminium and iron takes place down to 20 cm soil depth, while below 20 cm the silicate buffer is effective.

Along the altitudinal gradient, the “base saturation” (V-value) and cation exchange capacity (T-value) are very high in the A-/B-horizons of the soil profiles in Großalpwald (94.0–98.7/92.7–93.0% and 50.5–52.1/5.7–18.6 meq/100 g fine soil, respectively). Calcium is clearly the dominant cation. In Ragolerwald the “base saturation” and cation exchange capacity of the A-/B-horizons strongly differ with respect to the A-horizons below and above 1300 m: “base saturation”, 76.0/64.8% below 1300 m, 55.8/63.5% above 1300 m; cation exchange capacity, 19.3/8.2 meq/100 g fine soil below 1300 m, 15.8/6.6 meq/100 g fine soil above 1300 m.

Of all soil chemical factors measured only the Ca^{2+}/H^+ ratio reaches toxic values ($Ca^{2+}/H^+ < 1$) which can limit beech occurrence. Toxic values are observed in the main root space of the Gleyic and Gleyic-dystric Cambisols above 1300 m in Ragolerwald, and the Gleyic Podzol in Sardonawald. All other factors (pH, V-value, T-value, Ca^{2+}/K^+ , Ca^{2+}/Mg^{2+} , PO_4 , C/N) do not reach critical values which limit beech occurrence.

Edaphic limits for spruce occurrence in Großalpwald below 1600 m are locally possible because of unbalanced nutrient uptake (excessive supply of calcium in the calcium humates), and high susceptibility to drought

caused by the strong development of fine roots in the upper humus-rich strata of carbonate-rich soils. Sedimentation of shifting dust possibly makes an essential contribution to the nutrition of spruce in Sardonawald (1760 m) and helps to buffer high proton concentrations in the fine soil.

Results of the phytosociological studies

In Tamina and Calfeisen valleys the following forest communities have been found: Carici albae-Fagetum; Lonicero alpigenae-Fagetum; Abieti-Fagetum typicum; Abieti-Fagetum, *Carex alba*-variant; Carici albae-Abietetum; Galio rotundifolii-Abietetum; Veronico latifoliae-Piceetum; Sphagno-Piceetum calamagrostietosum villosae; Erico-Pinetum silvestris. The communities in the gaps of Großalpwald and Ragolerwald are: a) in young gaps: fragments of Abieti-Fagetum typicum, Abieti-Fagetum, *Carex alba*-variant and Erico-Pinetum silvestris; b) in old gaps: Rubetum idaei, Cicerbitetum alpinae, Sorbo-Calamagrostietum.

The continental gradient present in the South-North and West-East directions of Tamina and Calfeisen valleys, respectively, is reflected by the species spectrum of the forest communities and their sequences of occurrence. This gradient is modified by the foehn (as evidenced by Erico-Pinetum silvestris stands).

The fundamental significance of the 1300 m-"threshold" for the species composition and the structure of the forest communities can be documented as follows:

- tree-like beeches in Großalpwald above 1300 m having several stems (shrub-like populations, so-called "Legbuchen", are found close to Vättis at c. 1600 m in the area of avalanche tracks);

- discontinuities in the life-form proportions and compositions in *Piceetum* and *Abietetum* above 1300 m: a) increase of woody chamaephytes and therophytes, b) decrease of summer-green phanerophytes and geophytes;
- abrupt changes in the altitudinal course of the α -diversity of forests containing spruce (*Abietetum*, *Piceetum*) or beech (*Fagetum*, *Abieti-Fagetum*) above 1300 m, which shows significant parallels to the discontinuous altitudinal gradient of temperature;
- the rare or failing rejuvenation of beech above 1300 m.

Human impact is reflected in a lowering of the timber line (e.g. expansion of grassland, supply of fencepoles), the appearance of ridges and channels and the development of specific forest structures (e.g. supply of firewood, charcoal-burning). Impacts from the 19th and 20th centuries are directly and indirectly visible in the uniform, often unstable reforestation areas (e.g. risk of damage by storms), the heavy damage by deer and chamois (e.g. problems of rejuvenation of silver fir) and local climate changes (e.g. reservoirs).

In Ragolerwald on calcaric schists above 1300 m (transition zone), lasting processes of acidification must be considered, which have been induced by natural stressors (e.g. fluctuations of temperature, foehn, drought) and anthropogenic stressors (e.g. clear cutting, browsing, storm damages). The beech upper limit at 1300 m is both edaphic (being caused by proton concentrations which are toxic for beech), and abrupt (zone of abrupt transition). In Großalpwald on carbonate-rich material, there is no soil chemical limitation to the occurrence of beech. The beech upper limit at c. 1600 m is caused by climatic factors and approximates to the climatic limit for beech growth (zone of mosaic-like or

continuous transition). The integration of the Calfeisen valley into a group of "limit" types or "ecotone" types is uncertain because of the small number of soil chemical data.

The understanding of specific local conditions and the influence of natural stressors are essential prerequisites for the research of potential limits of tree species.

Woodland communities and woodland sites in the mountainous region of Canton of St. Gallen in eastern Switzerland

Waldgesellschaften und Waldstandorte im St. Galler Berggebiet

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HANS-ULRICH FREY

The classification of forest sites and forest communities in the mountainous region of the Canton St. Gallen (NE-Switzerland) was completely revised in 1989–1992. This gives a basis for a phytosociological mapping of this incompletely described region. A complete system of idealized types of phytosociological units was built using relevés from the literature and some additional new relevés. Problems arising with the analysis of large floristic data-sets which are collected in a non-objective way by various authors are discussed. It is assumed that the vegetation changes gradually and the system of types does not have the character of a natural system. The units and their borders have thus to be chosen. Multivariate methods have only limited value for the building of a system of types which should enable addressing of any community in the study area. Forming an idealized type requires that the various conceptions and hypotheses of the author of the relevés are included in the analysis.

Such ideal types are characterized and described in detail for 68 vegetation units. Besides floristic data the description includes environmental characteristics of the sites and the physiognomy of the vegetation. In order

to test the new system, a correspondence analysis and species indicator value analysis were conducted using only the floristic data of the types. On sites with one clear limiting environmental factor, types could also be formed with this method, whereas on mesic sites the classification was not accurate enough. Classification of these sites requires data of the environmental factors, especially those of the soil.

The usefulness of the system was tested by mapping 14 selected areas by several persons. The system had to be slightly modified during the mapping of the first 2700 ha out of 3400 ha, but after that the system could be regarded as more or less complete. Based on the units described a phytosociological system was formed. This was compared with previously described systems in Switzerland and in nearby areas in the neighbouring countries. Valuable information was obtained about several communities until now only described in other regions. Some new units were described. Several suggestions for the interpretation and improvement of the system of forest communities and forest sites in Switzerland are made.

Indication of soil nutrients in litter meadows. Vitality parameters of selected species and floristic parameters as indicators of soil nutrients in litter meadows in the Pre-Alps of the Canton of Zurich (northern Switzerland)

Zur Indikation von Bodennährstoffen in Streuwiesen. Vitalitätsmerkmale ausgewählter Arten und floristische Parameter als Nährstoffindikatoren in Streuwiesen des Zürcher Voralpengebietes.

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HANS-ULRICH GRAF

Lateral nutrient gradients and their impact on vegetation were investigated along transects. Three litter meadows surrounded by intensively used grassland situated in the pre-alpine foothill region of the Canton Zürich were selected as study sites. The availabilities of nitrogen, potassium and phosphorus were determined by soil analyses.

Parameters of vitality of 15 different species and floristic characteristics were examined to assess their suitability as indicators of soil nutrients. The species studied were *Angelica silvestris*, *Carex davalliana*, *Carex hostiana*, *Carex panicea*, *Filipendula ulmaria*, *Galium uliginosum*, *Holcus lanatus*, *Lysimachia vulgaris*, *Mentha aquatica*, *Molinia coerulea*, *Parnassia palustris*, *Phragmites communis*, *Potentilla erecta*, *Ranunculus nemorosus* and *Succisa pratensis*. The minimum number of parameters investigated was four (*Carex panicea*), the maximum number was twelve (*Ranunculus nemorosus*). The response of individual species to different levels of soil nutrient supply turned out to be very variable between the transects.

If the relations are to be significant for 70% of the transects, only three species and ten parameters can be regarded as suitable for indicating soil nutrients. *Filipendula ulmaria* indicated considerably higher soil nutrient supply. Overall vitality, maximum plant height and maximum leaf width were the

most accurate indicators. Overall vitality of *Molinia coerulea* and maximum plant height of *Lysimachia vulgaris* were also suitable as indicators of higher soil nutrient supply.

The vegetation of the transects was described by group similarities based on the fuzzy set theory. Relevés of the site, chosen according to phytosociological criteria, were used as reference groups. The similarities to communities on wet sites better indicate soil nutrient supply than the vitality of any species does. The best indicator is the similarity of the transect relevés to the Primulo-Schoenetum. Using the nutrient indicator values of the transect relevés weighted according to coverage can provide nearly as accurate results.

The application of a local relative reference system for monitoring of lateral gradients in nature conservation is discussed with regard to differences between fluctuations and successions.

For applied nature conservation it is recommended to use permanent transects for monitoring potential lateral eutrophication. On these transects, weighted nutrient indicator values or similarities to clearly defined vegetation types within the sites should be recorded.