# GAiA

ÖKOLOGISCHE PERSPEKTIVEN FÜR
WISSENSCHAFT UND GESELLSCHAFT
ECOLOGICAL PERSPECTIVES FOR
SCIENCE AND SOCIETY
3 | 2010

- IDENTITÄT UND REGIONALENTWICKLUNG
- THE IDEA OF CLIMATE CHANGE
- BIODIVERSITY

oekom verlag

*GAIA* is available online at *www.ingentaconnect.com/content/oekom/gaia*
www.oekom.de | B 54649 | ISSN 0940-5550 |
GAIAEA 19/3, 161–240 (2010)

# Evaluating a Forest Conservation Plan with Historical Vegetation Data

## A Transdisciplinary Case Study from the Swiss Lowlands

*Matthias Bürgi, Claude Steck, René Bertiller*

*We analysed a detailed forest vegetation survey from 1907 and historical forest management plans to establish links between forest types and the occurrence of plant species. Based on our findings, we formulate recommendations for reserve site selection. Our case study shows how applied historical ecology can help improve conservation measures.*

**Evaluating a Forest Conservation Plan with Historical Vegetation Data** – A Transdisciplinary Case Study from the Swiss Lowlands
*GAIA* 19/3 (2010): 204 – 212

**Abstract**

Forest types shaped by humans host a specific set of plant species that may disappear subsequent to the abandonment of traditional uses of the forest. To improve the effectiveness of conservation management for plant species associated with traditionally managed forests, information on historical forest conditions and plant occurrence is vital. In the Swiss Canton Zurich, an action plan to promote light forests has been initiated by the state office for nature protection. This action plan has defined a set of 172 target species for light forests. In order to evaluate in which forest types these species occurred historically, we combined a vegetation survey from 1907 from the wooded mountain range of Lägern (Switzerland) with information on forest structure in the early 20th century based on forest management plans. For 21 target species, 181 locations were determined and linked to historical forest structures. We recommend enhancing the effectiveness of the action plan for light forests by recreating coppice-with-standard forest on productive soils, considering the role of non-timber forest uses for ecosystem development, and engaging private forest owners to assist in the creation of light forest reserves.

**Keywords**

biodiversity, coppice stands, forest management, historical ecology, Switzerland, woodland history

Habitat loss is a prime cause of species extinction (Pimm and Raven 2000). Halting or even reverting the decline in biodiversity is only possible if habitats with high conservation value are identified, located, and appropriately managed (Stoll-Kleemann and Job 2008). In ecosystems shaped by humans, nature conservation should consider the characteristic set of natural and anthropogenic disturbances (Pressey et al. 2007).

In many European forests, the vegetation structure and composition developed under a multitude of forest uses and management types (Salbitano 1988, Kirby and Watkins 1998, Bürgi 2008). Consequently, information on human activities is especially important for understanding the current species composition (Hermy and Verheyen 2007, Josefsson et al. 2009).

Due to the introduction of modern forestry and the abandonment of traditional forest uses such as woodland pasturing and litter collecting, many European forests have become denser and darker (McCollin et al. 2000, Van Calster et al. 2008). Several studies have observed a decline in light-demanding plant species for these ecosystems in recent years (Stehlik et al. 2007, Van Calster et al. 2008).

For Switzerland, both the changes in forest use and management and the shift in forest vegetation are well documented, but these two trends have rarely been brought together (but see Gimmi et al. 2010). Changes in forest management have been analysed in the Swiss lowlands (Bürgi 1999, Bürgi and Schuler 2003) as well as in alpine areas (Gimmi et al. 2008). Changes in vegetation over hundred years have been reconstructed on the wooded mountain range of Lägern by studying old herbarium specimens, excursion notes, and publications, and comparing them with the

**Contact:** *PD Dr. Matthias Bürgi* | Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) | Research Group Land Use History | Zürcherstr. 111 | 8903 Birmensdorf | Switzerland | Tel.: +41 44 7392354 | E-Mail: matthias.buergi@wsl.ch

*Dr. Claude Steck* | FrInaT – Freiburger Institut für angewandte Tierökologie GmbH | Freiburg | Germany | E-Mail: steck@buero-brinkmann.de

*Dipl.-Forsting. René Bertiller* | Wald – Natur – Landschaft | Winterthur | Switzerland | E-Mail: rene@bertiller.ch

present flora (Egloff 1991). Several light-demanding plant species typical of forests or forest edges have disappeared entirely or declined in population size or in the number of occurrence sites. Changes in microclimate – especially increased shading – have been considered the predominant cause of species loss. Similarly, a general decline in the average light indicator values over 50 years has been reported based on repeated vegetation sampling on forest plots in Switzerland (Kuhn et al. 1987, Kuhn 1993).

The reported decline in light-demanding forest plant species has caught the attention of nature conservationists. In the Swiss Canton Zurich, an action plan to promote light forests (Abegg et al. 2005) has been initiated by the state office for nature protection (Fachstelle Naturschutz Kanton Zürich). In this action plan, a set of 172 target species for light forests (figure 1) has been compiled taking into account the responsibility of the Canton to protect and foster species specified in the conservation master plan for Zurich (Kuhn et al. 1992), as well as experts' assessments of the species' dependency on light forests. However, reserves are not selected primarily due to ecological criteria. In fact, potential new reserves are proposed by the various forest owners, e.g., municipalities or forest cooperatives. A procedure for prioritising existing and proposed light forest reserves has been established based on the occurrence of target species and the forestry operations needed, such as initial logging to increase light availability and periodic interventions to maintain the open stand characteristics (Bertiller et al. 2006). This procedure makes it possible to select the most valuable forest stands among the proposed sites.

The action plan aims to create and maintain 1,000 hectares of light forests within a total forest area of 47,500 hectares. By 2007, about 350 hectares of light forests had been created. A perform- >

**FIGURE 1:** The list of target species in the action plan to promote light forest species (Abegg et al. 2005) encompasses attractive plants. The yellow foxglove *(Digitalis lutea)* (left) grows on dry, chalky, stony, and warm soils at sunny places. In the Canton Zurich the species occurs almost only on the Lägern. The peach-leaved bellflower *(Campanula persicifolia)* is one of the more common target species in light forests. It is often found on mowed roadsides or at forest-road slopes (where the crown canopy is not entirely closed).

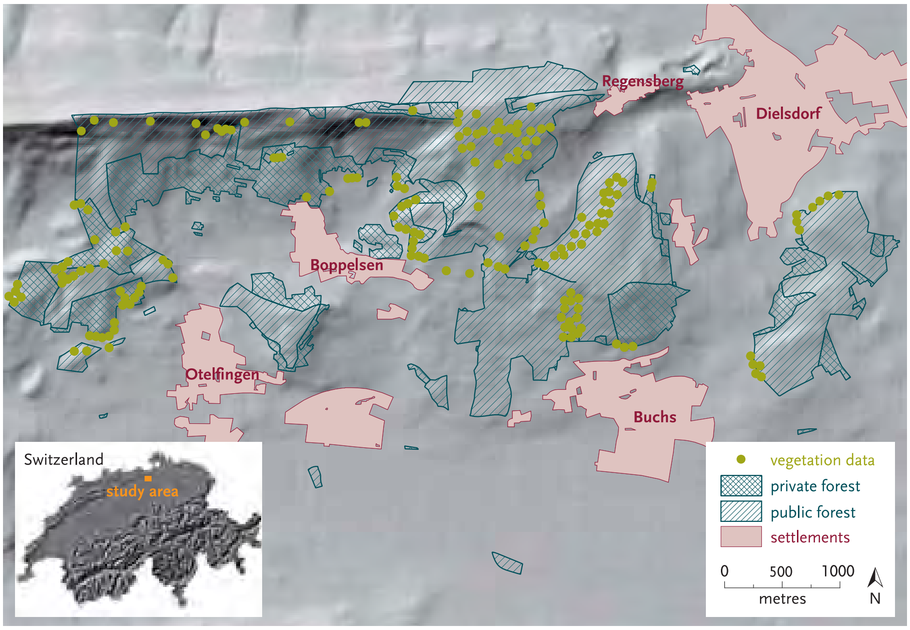




**FIGURE 2:** Forests in the study area are owned publicly and privately. Forest management plans exist for public (including cooperative) forests. Data source: vegetation data are based on Rikli (1907), and the map on dhm25 © 2009 Swisstopo (DV033492.2), Vector 25 © 2009 Swisstopo (DV033594).

ance review conducted in 2007 revealed that 76 of the 172 target species did not occur in any of the reserves delineated. Apparently, the reserves selected do not contain all necessary habitat types to include the entire pool of target species. This triggered interest in the question under what conditions the missing species were once present, and what measures have to be taken to increase the number of target species in the reserves.

Links between historical species occurrence and habitat characteristics can only be established if data on historical vegetation are combined with data on historical forest use and management.

We had the opportunity to test this link on the small wooded mountain range of Lägern (northern Switzerland), as the local vegetation was surveyed over a hundred years ago (Rikli 1907). Forest use, management, and structure at the time can be derived from forest management plans (Bürgi 1999, Axelsson et al. 2002).

Based on these two main sources, we address the following questions:

1. What historical light forest types were present on the Lägern at the beginning of the 20$^{th}$ century? What did they look like and what area did they cover?
2. Which plant species listed today as target species in the action plan to promote light forests (Abegg et al. 2005) occurred once on the Lägern?
3. How do these results translate into recommendations to improve the effectiveness of the action plan?

## Study Area

The study area covers about 1,000 hectares of forests on an altitudinal gradient from about 450 to 866 metres above sea level. It is situated on the southern slope of the Lägern, which forms the eastern most part of the Jura Mountains. This limestone mountain range stretches from eastern France to northern Switzerland. The forests belong to five municipalities: Otelfingen, Boppelsen, Buchs, Regensberg, and Dielsdorf, all in Canton Zurich (figure 2).

## Data

The historical vegetation data were taken from Rikli's study *Das Lägerngebiet* (1907). This study is exceptionally detailed and includes descriptions of the vegetation as well as a map showing the exact locations of a subset of the species recorded (scale 1 : 25,000). The data were most probably collected between 1900 and 1907.

The forest structure was reconstructed mainly based on forest management plans. Forest management plans are the most important planning tool in forestry. They include a report on the previous use of the forests, a description of their current state (e. g., tree species composition), and guidelines for future management. These plans have been available since about 1880 for all non-private (i. e., community or cooperative) forests in the study area. For our study, we selected all plans issued in roughly the same period as Rikli's study, resulting in a total of 15 forest management plans from 1872 to 1926 (State Archive in Zurich, signatures in the range Z31 1350 to Z31 1466). To reflect the informal character of the plans, we use the English translations of the German names used in the sources: spruce is *Picea abies,* larch is *Larix decidua,* pine is *Pinus sylvestris,* beech is *Fagus sylvatica,* fir is *Abies alba,* but oak, like the German Eiche, can be either *Quercus robur* or *Quercus petraea.*

Aerial photographs from 1943/44 and 1952 (source: Swisstopo[1]) were analysed as an additional means to identify and locate historical forest types, especially for the private forests, which are not covered by the management plans.

## Methods

To assess and locate the historical light forests, we defined a set of historical forest types for Canton Zurich, based on adequate classification criteria. For this task, an extensive literature search was conducted and complemented by targeted archival research.

1 *www.swisstopo.admin.ch*

Most of the information was taken from Huber (1942), Krebs (1948), and Bürgi (1998).

The forest area at the time was first digitised in ArcGIS (ESRI), based on a topographical map from around 1900 (*Siegfriedkarte,* provided by Swisstopo[1] [DV 033492.2]). The forest management plans contain maps depicting the management compartments, which are often further divided into sub-compartments. As all information on forest structure and tree species composition is structured by compartments and, sometimes, sub-compartments, compartment boundaries were located and digitised within the digitised forest area. Sub-compartments, which were only listed and described in the stand description parts of the forest management plans, were – wherever possible – located with the help of the aerial photographs from 1943/44 and 1952. In cases where sub-compartments could not be located, all information was summarised on the compartment level (details in Gimmi et al. 2008). Each forest patch was assigned to a historical forest type.

From the plant species mentioned in Rikli (1907), we selected all species also listed as target species in the action plan (Abegg et al. 2005), and from these those we could localise on the map. As most target species occur at different locations, the number of occurrences surpasses the number of target species. We then assessed the numbers of light forest species and their cumulative occurrences in the different forest types. We could thus determine which forest types bear the highest potential for fostering target species, by a procedure which corresponds to the selection criteria for light forest reserves applied in the Canton Zurich (Bertiller et al. 2006).

## Results

### Typology of Historical Forests

Based on an extensive literature study (Bürgi 2009), we propose distinguishing seven types of historical light forests: private forests, stands including open areas, floodplain coppice forests, other coppice forests, coppice-with-standard forests (with few standards [$<100\,m^3/ha$], medium density of standards [100 to 200 $m^3/ha$], and many standards [$>200\,m^3/ha$]), pine (high) forests, and oak high forests. As for the historical non-light forest types, we distinguished between freshly planted stands and high forest stands.

Private forests in Canton Zurich were historically characterised by their special ownership structure and intensive use (Bürgi 1998), mainly focussing on the owner's needs and including forest pasturing and litter collecting (Forststatistik 1880). The average size of private forest plots was far below 0.5 hectares in many municipalities in Canton Zürich. In the district of Andelfingen, for example, 424 hectares of private forests were divided into 2,460 plots (Meister 1875). The intensive use of private forests led to low growing stocks of merely 60 to 120 cubic metres per hectare (Steiner 1954), which justifies classifying them as light forests. For our study, we assumed an average growing stock in private forests of 90 cubic metres per hectare (figure 3).

### Historical Light Forest Types on the Lägern

According to the historical map analysis, at the beginning of the $20^{th}$ century forests covered 1,003 hectares in the study area, of which 622 hectares were public forests. This figure corresponds well to the 615 hectares specified in the forest management plans as the area covered by all non-private forests in the study region (figure 3). All stands were assigned to one of the historical forest types.

Figure 3 shows the areas covered by the different forest types. Private forests were mostly located in the vicinity of the settlements (figure 2). About two-thirds of the public forests were covered by one of the types of coppice or coppice-with-standard forests. Coppice forests were mostly located along the ridge top of the Lägern. The light forest types "stands including open areas", "floodplain coppice forests", and "oak high forest" were not found in the study region. In total, about 90 percent of all forests in the study region assessed in the early $20^{th}$ century fall within one of the historical light forest categories.

### Historical Forest Structure and Tree Species Composition

The average timber volume of coppice forests was characteristically low ($50\,m^3/ha$, figure 3). A similar timber volume was observed in the understorey of the two types of coppice-with-standard forests with a low or medium density of standards (data not shown). In the class with many standards, where the amount of growing stock in the standards surpassed 200 cubic metres per hectare, the growing stock in the understorey amounted to only 29 cubic metres per hectare. Pine forests, and especially the other high forests, had markedly more growing stock (figure 3).

For most of the historical forest types in public forests (except young stands and coppice forests), the management plans indicate the amount of growing stock for each tree species, which can

>

**FIGURE 3:** Area covered and growing stock for all forest types occurring in the early $20^{th}$ century on the Lägern (data source: forest management plans, and, for the growing stock in private forests, the general literature – see text). The values given for coppice-with-standard (CWS) forests include the coppice layer and the standards.

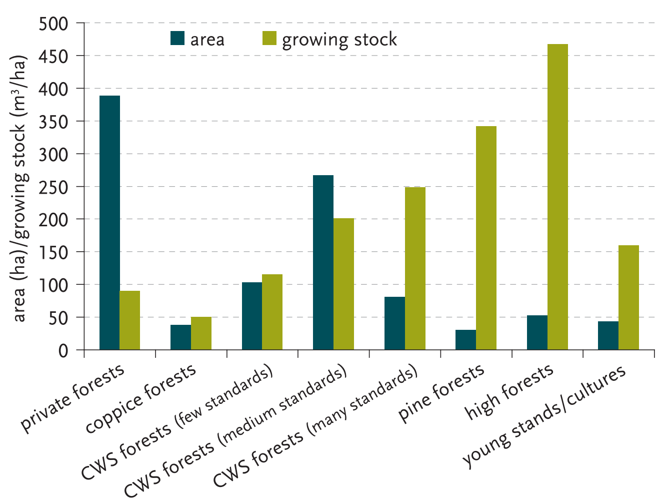


**TABLE:** Species composition of selected historical forest types in the Lägern area at the beginning of the 20th century according to the proportions in growing stock (source: forest management plans). CWS: coppice with standard, BL: broadleaved species. Corresponding to the wording in the management plans, the colloquial names of the tree species are given. The values for CWS forests comprise the coppice layer and the standards.

| forest types | spruce (%) | fir + larch (%) | pine (%) | oak (%) | beech (%) | other BL (%) |
|---|---|---|---|---|---|---|
| **CWS forests (few standards)** | 19.0 | 0.0 | 19.6 | 13.5 | 7.8 | 40.2 |
| **CWS forests (medium standards)** | 48.3 | 6.0 | 5.3 | 11.3 | 6.0 | 23.1 |
| **CWS forests (many standards)** | 60.3 | 8.4 | 5.6 | 8.0 | 2.7 | 15.1 |
| **pine forests** | 18.7 | 0.0 | 76.5 | 0.5 | 0.1 | 3.6 |
| **high forests** | 64.0 | 4.9 | 20.9 | 4.9 | 1.3 | 4.2 |

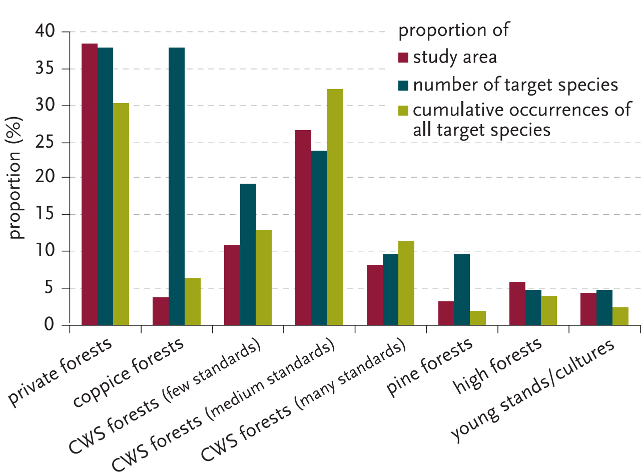
be interpreted as tree species composition (see table above). Not surprisingly, pine forests were in fact dominated by pine, whereas the other high forests, as well as the coppice-with-standard forests with medium to high densities of standards, were dominated by spruce. The highest density of oak is recorded in the coppice-with-standard stands with few standards. As coniferous species do not re-sprout after being cut, the coppice layer generally consisted exclusively of broadleaved species. Consequently, the proportion of "other broadleaved species" is highest in the coppice-with-standard forests with only a few standards, where the coppice layer contributes relatively more to the total species composition.

### Light Forest Target Species Listed in Historical Vegetation Data

Out of the 172 target species listed in the action plan to promote light forests (Abegg et al. 2005), 37 species are mentioned by Rikli (1907). For 21 of these, 181 exact locations were determined from information in Rikli's text or map, and entered into the GIS.

If the relative area covered by the different forest types is compared with the proportion of the number of target species represented and the proportion of their cumulative occurrences (all target species) within each forest type area, interesting patterns become apparent (figure 4): The coppice forests were most diverse, including eight of 21 target species (38.1 percent) on only 3.7 percent of the area. The coppice-with-standard forests with a high density of standards, in contrast, included only two target species on 8.0 percent of the forest area. All types of coppice and coppice-with-standard forests included more occurrences of target species than to be expected according to the area covered.

**FIGURE 4:** The target species listed in the recent action plan for promoting light forest species (Abegg et al. 2005) were not distributed evenly over the different light forest types around the beginning of the 20th century. Data sources: Rikli (1907), forest management plans, Swisstopo (DV 033492.2). CWS: coppice with standard.




### Additional Information on Forest Use and Management

The anthropogenic impact on forest is, of course, not limited to forest management and the corresponding different forest types and their characteristic structure. The forest management plans and published studies document, in the northern part of Canton Zurich, widespread non-timber forest uses, such as woodland pasturing, litter collection, temporary agricultural use of the clearings, collection of oak bark for leather tanning, and grass cutting (Bürgi 1999). In the study area, litter collecting seems to have been of special relevance up to the early 20th century (Bürgi 1998), and woodland pasturing was also reported up to the beginning of the 20th century (Egloff 1991). The sources do not allow a spatially and temporally precise picture to be constructed about when and where these practices were performed and abandoned. The ecological effect of their long-term performance should still, however, be considered in the design of reserves and management guidelines.

## Discussion

### Data Requirements and Quality

Studies of changes in forest vegetation have to be based on historical data on flora, with sufficient information on the locality of the plants to enable a repetition of the vegetation samples (Klecak et al. 1997 – for discussion of the methodological problems of comparing historical and modern vegetation data, see Tingley and Beissinger 2009). But even for the last 100 years, spatially precise information on forest vegetation in Central Europe is scarce (Schuler 1998). Literature and historical herbaria for the 19th century, or even before, may allow the analysis of vegetation changes on a regional or sometimes a local scale (e.g., Shaffer et al. 1998, McCollin et al. 2000, Spillmann and Holderegger 2008), but their spatial precision is usually insufficient to link the information to forest stands and their structural characteristics.

The data used for the study presented (Rikli 1907) do not meet the standards of modern vegetation science. Although there does not seem to be any specific bias towards, e.g., forest types, special plant groups, or topographic or edaphic conditions, a bias in sampling cannot be ruled out. We therefore refrained from performing statistical analyses which could result in over-interpreting the data, and we are cautious about the overall interpretation.

### Historical Light Forests

We used information on stand characteristics extracted from historical forest management plans and applied our own typology for historical forests, to classify more than 90 percent of the forest area in the early 20th century as "light forest". The modern policy to restore the typical flora associated with light forests (figure 5), specified in the action plan to promote light forests (Abegg et al. 2005), only calls for about 2.1 percent of the forest area to be restored to light forest conditions. Given the range and number of modern demands put on the forests, this is probably reasonable. However, the larger proportion once covered by light forests according to our findings indicates it would be wise to choose these 2.1 percent carefully. Otherwise it will not to be possible to re-establish the 172 target species listed in the action plan. The finding that 76 target species did not occur in any of the light forest reserves created so far might reflect the sub-optimal placement of these reserves.

The stand characteristics of the light forests on the Lägern in the early 20th century show that the proportion of spruce in coppice-with-standard forests, especially in those with a medium or high density of standards, is similar to the proportion of spruce in high forest stands (see table). This observation contrasts with the common perception that coppice-with-standard forests have to be dominated by oak and hornbeam (e.g., von Hornstein 1951, Hasel 1985), but has been corroborated by other studies as a specialty of north-eastern Switzerland (Surber 1950, Voegeli 1950, Leibundgut 1971, Bürgi 1998).

### Importance of Historical Light Forest Types for Target Species

The light availability in forests in the Swiss lowlands has been found to have declined as a result of a general increase in timber volume, changes in tree species composition (i.e., a trend from oak and pine to beech and spruce), and changes in forest management, especially the abandonment of coppice management (Bürgi 1998, 1999). Our study supports the finding that coppice and coppice-with-standard forests are very relevant for the con- >

**FIGURE 5:** The blue lettuce *(Lactuca perennis)* grows on sunny dry grasslands or on rocky hillsides on limesoil (such as, e.g., the Lägern). In forests, plants only grow if they receive a lot of sunlight.

**FIGURE 6:** In coppice-with-standard forests, the understorey is cut every 15 to 25 years. In the first years after a cut, the stands are fairly open, with optimal growing conditions for light forest species. © WSL Photoarchiv A1081 (Rümlang, Mittelwaldbild, zwei Jahre nach dem Schlag, 1924)

servation of light forest target species (figure 6). Decocq et al. (2005) even found the highest number of forest plant species in coppice-with-standard stands and suggest distinguishing forest species from "coppice-woodland species".

The high proportion of spruce in the coppice-with-standard forests illustrates that species-rich coppice-with-standard forests do not necessarily have to be dominated by oak. However, since oaks are important for insects (Southwood 1961, Kennedy and Southwood 1984), it might well be that the effect looks different for fauna than it does for flora. In any case, if the growing stock surpasses a threshold of about 200 to 250 cubic metres per hectare (figure 3), high proportions of coniferous species seem to go parallel with a lower abundance of light-forest species.

The documented history of non-timber forest uses in the wider study area underlines the importance of considering the effect of multiple anthropogenic disturbances on forest ecosystems. In many of the historical light forest types, woodland pasturing and litter collecting caused most likely a significant nutrient export (see Gimmi et al. 2008). These extractive activities contributed to forest conditions that were not only lighter than today, but also lower in nutrients (Wohlgemuth et al. 2002). General considerations imply that non-timber forest uses were performed wherever an adequate return for the time invested could be expected. As soon as alternative resources or products were available at affordable costs, traditional practices were abandoned. Forest litter, for example, was collected until ample straw was imported by railroad, and its use was taken up again in some regions during World War One and World War Two, when importing straw became more difficult (Bürgi 1998).

**Limitations of the Study**

Before specific recommendations can be formulated, some constraints of the study have to be considered. Forest vegetation is not only influenced by forest use and management, but additionally by a whole range of factors which are only partly and/or indirectly linked to human activities, such as climate, density of ungulates, natural disturbances, invasive species, and the atmospheric deposition of nutrients or toxic substances. Only those factors can be considered for which ample information is available. Given the widely reported decline in light-demanding species in European forests (Stehlik et al. 2007, Van Calster et al. 2008), we assume that the changes in microclimatic conditions in forest stands were foremost influenced by the increasing density and growing stock in forest stands, which tend to overrule the effects of climate change. An increase in ungulate population is likely, given that during the 19th century, the numbers were small due to centuries of intensive hunting (Breitenmoser 1998). During the 1930s, foresters in Canton Zurich started complaining more about damage due to browsing (Bürgi 1998). It seems thus likely that the effects of abandoned woodland pasturing were to a certain extent counterweighted by increasing numbers of ungulates, although their browsing effect differs from the impact by herded cattle, pigs, and goats in intensity, timing, and duration. A completely different development took place when litter collecting was abandoned. The associated reduction in nutrient export was not counterweighted, but instead

**FIGURE 7:** Nowadays, light forest reserves are often placed on marginal land, where timber production is not profitable. Historically, however, light forests also occurred on productive forest land.

further accentuated by an increase in atmospheric deposition of nutrients, especially of nitrogen (Flückiger and Braun 1998).

**Recommendations for the Action Plan**

We thus propose improving the effectiveness of the action plan to promote light forests for Canton Zurich (Abegg et al. 2005) as follows.

1. ***Light forest reserves should be established not only on marginal land, but also on more productive soils.*** As the reserve selection is based on suggestions of forest owners and the respective foresters in charge, light forest reserves are often created on marginal land, i. e., steep and stony terrain with shallow soils on which timber production is not profitable (figure 7). Historically, light forests were not restricted to marginal growing conditions, but also occurred on deep soils in flat terrain. We therefore suggest motivating forest owners to create additional reserves on more productive soils, to represent the whole diversity of growing conditions.

   Our study shows that especially coppice and coppice-with-standard forests are important for the protection of light forest species. Coppice-with-standard forests do not have to be dominated by broadleaved species. High proportions of spruce as standards do not seem to suppress the presence of light-forest species, as long as the growing stock does not exceed a certain limit of, e. g., 200 to 250 cubic metres per hectare.
2. ***Apart from light conditions, changes in nutrient availability in forest soils should be considered.*** The concept of light forests should not only focus on historical light conditions but should also include nutrient availability. Changes in nutrient level in forest soils must be considered in the design of any management measure aiming at recreating past habitat conditions, e. g., by reintroducing woodland pasturing and litter collecting. Experiments have been established to study the ecological effects of litter removal (Bürgi et al. 2006). The action plan might additionally initiate systematic reviews and experiments on the ecological impact of different non-timber forest uses on various forest ecosystems.
3. ***An additional programme should be set up to address the specific needs and circumstances of private forest owners.*** Forests can be managed sustainably with very different levels of productivity and growing stock. Our study indicates that growing stock in historical light forests was generally less than 150 to 200 cubic metres per hectare, compared to about 357 cubic metres per hectare in public forests today (data for 2005[2]). In private forests, growing stock has even increased about five times, from merely 90 to 462 cubic metres per hectare, i. e., they changed from being very open, light forests to being especially dense forests. We suggest that an additional programme specifically addressing private forest owners could improve the effectiveness of the action plan, as private forests experienced the most dramatic changes regarding light conditions. Based on studies in other parts of the canton (Bürgi 1998), no major shifts between private and public ownership are to be expected for the last 150 years. We therefore can assume that most of today's private forests experienced this development. Combining information on historical or contemporary populations of underrepresented light forest target species with habitat suitability modelling could be used to delineate high priority areas for additional forest reserves on private forest land. The forest owners affected could then be financially and logistically supported and intensive logging and maintenance measures planned.

Changes in forest use, forest structure, and the ecological context of forest ecosystems should be systematically assessed to make conservation planning more efficient and effective in forest ecosystems strongly shaped by human impact. Attempts to simply restore forests to an earlier historical state are anachronistic (Jackson and Hobbs 2009, Hall 2010). But knowledge on historical states will lead to a more informed design and management of ecosystems.

This study has been financially supported by Canton Zurich's Fachstelle Naturschutz. We thank three anonymous reviewers for helpful comments on an earlier version of this paper, and *Silvia Dingwall* for her language correction.

## References

Abegg, B., S. Wegmann, M. Fehr, H. P. Stutz, A. Hofmann, A. Keel. 2005. *Aktionsplan Lichte Wälder im Kanton Zürich.* Zurich: Volkswirtschaftsdirektion des Kantons Zürich.

Axelsson, A. L., L. Östlund, E. Hellberg. 2002. Changes in mixed deciduous forests of boreal Sweden 1866–1999 based on interpretation of historical records. *Landscape Ecology* 17: 403–418.

Bertiller, R., A. Keel, H.-P. Stutz. 2006. Bewertung Lichter Wälder im Kanton Zürich und der Nutzen für das Projektmanagement. *Schweizerische Zeitschrift für Forstwesen* 157: 303–309.

Breitenmoser, U. 1998. Large predators in the Alps: The fall and rise of man's competitor. *Biological Conservation* 83: 279–289.

Bürgi, M. 1998. Waldentwicklung im 19. und 20. Jahrhundert. Veränderungen in der Nutzung und Bewirtschaftung des Waldes und seiner Eigenschaften als Habitat am Beispiel der öffentlichen Waldungen im Zürcher Unter- und Weinland. *Beiheft Schweizerische Zeitschrift für Forstwesen* 84: 1–234.

Bürgi, M. 1999. A case study of forest change in the Swiss lowlands. *Landscape Ecology* 14: 567–575.

Bürgi, M. 2008. Historische Ökologie – ein interdisziplinärer Forschungsansatz, illustriert am Beispiel der Waldstreunutzung. *GAIA* 17/4: 370–377.

Bürgi, M. 2009. *Typisierung der historisch lichten Wälder im Kanton Zürich.* Unveröffentlichter Bericht. Zurich: Fachstelle Naturschutz Kanton Zürich.

Bürgi, M., A. Schuler. 2003. Driving forces of changes in forest management – An analysis of regeneration practice in the forests of the Swiss lowlands during the 19th and 20th century. *Forest Ecology and Management* 176: 173–183.

Bürgi, M., T. Wohlgemuth, S. Zimmermann. 2006. Austragsnutzungen im Wald. *Zürcher Wald* 5: 28–29.

Decocq, G. et al. 2005. Silviculture-driven vegetation change in a European temperate deciduous forest. *Annals of Forest Science* 62: 313–323.

Egloff, F. G. 1991. Dauer und Wandel der Lägernflora. *Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich* 136: 207–270.

>

2 *www.wald.kanton.zh.ch*

Flückiger, W., S. Braun. 1998. Nitrogen deposition in Swiss forests and its possible relevance for leaf nutrient status, parasite attacks and soil acidification. *Environmental Pollution* 102/S1: 69–76.
Forststatistik. 1880. *Forst-Statistik des Kantons Zürich.* Winterthur: Bleuler-Hausheer.
Gimmi, U., M. Bürgi, M. Stuber. 2008. Reconstructing anthropogenic disturbance regimes in forest ecosystems – A case study from the Swiss Rhone valley. *Ecosystems* 11: 113–124.
Gimmi, U., T. Wohlgemuth, A. Rigling, C. W. Hoffmann, M. Bürgi. 2010. Land-use and climate change effects in forest compositional trajectories in a dry Central-Alpine valley. *Annals of Forest Science* 67: 701 doi: 10.1051/forest/2010026.
Hall, M. 2010. *Restoration and history. The search for a usable environmental past.* New York, NY: Routledge.
Hasel, K. 1985. *Forstgeschichte. Ein Grundriss für Studium und Praxis.* Pareys Studientexte 48. Hamburg: Paul Parey.
Hermy, M., K. Verheyen. 2007. Legacies of the past in the present-day forest biodiversity: A review of past land-use effects on forest plant species composition and diversity. *Ecological Research* 22: 361–371.
Huber, A. 1942. Beobachtungen und Untersuchungen über den Zustand der Privatwälder im nördlichen Kanton Zürich. *Mitteilungen der Naturforschenden Gesellschaft Schaffhausen* 28: 135–157.
Jackson, S. T., R. J. Hobbs. 2009. Ecological restoration in the light of ecological history. *Science* 325: 567–569.
Josefsson, T., G. Hörnberg, L. Östlund. 2009. Long-term human impact and vegetation changes in a boreal forest reserve: Implications for the use of protected areas as ecological references. *Ecosystems* 12: 1017–1036.
Kennedy, C. E. J., T. R. E. Southwood. 1984. The number of species of insects associated with British trees: A re-analysis. *Journal of Animal Ecology* 53: 455–478.
Kirby, K. J., C. Watkins (Eds.). 1998. *The ecological history of European forests.* Wallingford, UK: CABI.
Klecak, G., T. Wohlgemuth, J. J. Schneller. 1997. Regionale Florenwerke und ihre Bedeutung für die Rekonstruktion räumlicher und zeitlicher Dynamik seltener Pflanzenarten. *Botanica Helvetica* 107: 239–262.
Krebs, E. 1948. *Die Waldungen der Albis- und Zimmerbergkette.* Winterthur: Genossenschafts-Buchhandlung.
Kuhn, N. 1993. Ursachen floristischer und ökologischer Vorgänge in Waldbeständen. *Schweizerische Zeitschrift für Forstwesen* 144: 347–367.
Kuhn, N., R. Amiet, N. Hufschmid. 1987. Veränderungen in der Waldvegetation der Schweiz infolge Nährstoffanreicherungen aus der Atmosphäre. *Allgemeine Forst- und Jagdzeitung* 158: 77–84.
Kuhn, U., C. Meier, B. Nievergelt, U. Pfaendler. 1992. *Naturschutz-Gesamtkonzept für den Kanton Zürich.* Zurich: Amt für Raumplanung.
Leibundgut, H. 1971. Über den Zuwachs und Ertrag von Mittelwaldfichten. *Schweizerische Zeitschrift für Forstwesen* 122: 230–239.
McCollin, D., L. Moore, T. Sparks. 2000. The flora of a cultural landscape: Environmental determinants of change revealed using archival sources. *Biological Conservation* 92: 249–263.
Meister, U. 1875. *Betrachtungen über die zürcherische Privatforstwirthschaft.* Zurich: Herzog.
Pimm, S. L., R. Raven. 2000. Biodiversity: Extinction by numbers. *Nature* 403: 843–845.
Pressey, R. L., M. Cabeza, M. E. Watts, R. M. Cowling, K. A. Wilson. 2007. Conservation planning in a changing world. *Trends in Ecology and Evolution* 22: 583–592.
Rikli, M. 1907. Das Lägerngebiet. *Berichte der Schweizerischen Botanischen Gesellschaft* 17: 5–83.
Salbitano, F. (Ed.). 1988. *Human influence on forest ecosystem development in Europe.* Proceedings of a workshop held in Trento, Italy, 26–29 September 1988. Bologna: Pitagora.
Schuler, A. 1998. Sustainability and biodiversity – Forest historical notes on two main concerns of environmental utilisation. In: *Assessment of biodiversity for improved forest planning.* Edited by P. Bachmann, M. Köhl, R. Päivinen. Dordrecht: Kluwer. 353–560.
Shaffer, H. B., R. N. Fischer, C. Davidson. 1998. The role of natural history collections in documenting species declines. *Trends in Ecology and Evolution* 13: 27–30.
Southwood, T. R. E. 1961. The number of species of insect associated with various trees. *Journal of Animal Ecology* 30: 1–8.
Spillmann, J. H., R. Holderegger. 2008. Die Alpenpflanzen des Tössberglandes. Einhundert Jahre nach Gustav Hegi. *Bristol-Schriftenreihe* 22: 1–220.
Stehlik, I., J. P. Caspersen, L. Wirth, R. Holderegger. 2007. Floral free fall in the Swiss lowlands: Environmental determinants of local plant extinction in a peri-urban landscape. *Journal of Ecology* 95: 734–744.
Steiner, D. 1954. *Die Waldgeschichte des oberen Tösstales.* PhD diss., ETH Zurich.
Stoll-Kleemann, S., H. Job. 2008. The relevance of effective protected areas for biodiversity conservation: An introduction. *GAIA* 17/S1: 86–89.
Surber, E. 1950. Untersuchungen an Mittelwaldfichten im nordost-schweizerischen Laubmischwaldgebiet. *Mitteilungen der Eidgenössischen Anstalt für das forstliche Versuchswesen* 16: 635–681.
Tingley, W. T., S. R. Beissinger. 2009. Detecting range shifts from historical species occurrences: New perspectives on old data. *Trends in Ecology and Evolution* 24: 625–633.
Van Calster, H., R. Vandenberghe, M. Ruysen, K. Verheyen, M. Hermy, G. Decocq. 2008. Unexpectedly high 20th century floristic losses in a rural landscape in northern France. *Journal of Ecology* 96: 927–936.
Voegeli, H. 1950. Der Mittelwald als Studienobjekt für waldbauliche Fragen. *Schweizerische Zeitschrift für Forstwesen* 101: 586–589.
von Hornstein, F. 1951. *Wald und Mensch. Waldgeschichte des Alpenvorlandes Deutschlands, Österreichs und der Schweiz.* Ravensburg: Otto Maier.
Wohlgemuth, T., M. Bürgi, C. Scheidegger, M. Schütz. 2002. Dominance reduction of species through disturbance – A proposed management principle for central European forests. *Forest Ecology and Management* 166: 1–15.

*Submitted March 9, 2010; revised version accepted July 9, 2010.*

***Matthias Bürgi***

Born 1967 in Berne. Studies in environmental sciences at ETH Zurich. PhD in 1997. 1998 to 2001 postdoctoral researcher at Harvard University, Cambridge, MA, and at the University of Wisconsin, Madison, WI. Afterwards senior researcher at the chair of Nature and Landscape Protection, ETH Zurich. 2006 habilitation in historical ecology at ETH Zurich. Since 2006, leader of the research group Land Use History at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmensdorf, Switzerland. Since 2004, winemaker at the Lake of Zurich.

***Claude Steck***

Born 1974 in Basel. Studies in biology at the University of Zurich. Research fellow at the chair of Nature and Landscape Protection, ETH Zurich. 2007 PhD from ETH Zurich. Since 2007 works for FrInaT – Freiburger Institut für angewandte Tierökologie GmbH, Freiburg, Germany.

***René Bertiller***

Born 1975 in Basel. Studies in forestry at ETH Zurich. 2002 to 2005 assistant at the chair of Nature and Landscape Protection, ETH Zurich. Since 2002 freelance works in the domains of reserve management, vegetation surveys, and forest planning.