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Insights from 50 years of research in natural forest dynamics in Switzerland

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Summary

Thirty-seven forest reserves distributed over different vegetation belts of Switzerland have been studied since 1955 to gain a better understanding of forest succession in unmanaged forests. The reserves were founded between 1910 and 1979, but timber harvesting had usually ceased earlier. Reserve size ranges from 0.6 ha to 245 ha. The research method combined periodical measurements of individual trees (diameter at 1.3 m height ≥ 4 cm) on 299 permanent plots (size 0.1-3.5 ha), and full callipering in forest compartments (size 2-8 ha). The number of inventories ranges from 1 to 7, with a median of 3.

Several trends are consistently found in most reserves: a) an increase in basal area and growing stock; b) a decrease in stem number; c) an increase in the number of large trees, and d) a reduction of tree species richness, particularly in deciduous forests. In the reserves studied, only few disturbances occurred. In natural forest succession, these trends would be expected in early- to mid-successional stages ('optimal phase', or 'stem exclusion' to 'understory reinitiation' stages). This is in line with the stand history of many of the reserves which originate from early successional stands.

In 2006, the research program in reserves was refocused. The methods were adapted to meet information needs regarding dead wood and habitat structures such as tree hollows and broken crowns. First results show highly variable amounts of dead wood and densities of habitat structures. Continuous monitoring will reveal whether the trends found so far hold in the long term.

Keywords

Forest reserves, Switzerland, permanent plot, stand structure, habitat structures

Introduction

The value of old-growth, natural or unmanaged forests was increasingly recognized in the last 100 years. The Scatlè reserve in the Grisons, which was assigned a protected status in 1907, was the first forest to be spared on purpose from management in Switzerland. Today, the official goal of Swiss policy is to assign full protection to 5% of the forest area, and management for conservation to another 5%.

Conservation NGO's and scientists had an important role in the establishment of forest reserves in Switzerland. From 1948 to 1982, the chair of silviculture at ETH (Zurich) established contractual agreements about new reserves with >30 forest owners, and conducted research about forest dynamics using repeated forest inventories until 2006. The goal of this research was to understand the structural development of forests in the absence of silvicultural management, and was intended to contribute to close-to-nature silviculture in managed forests, i.e. a management type which uses natural processes as much as possible to reach management goals (Leibundgut 1959, 1962). In this paper, we present selected results this long-term research.

Methods

The research network consisted of thirty-seven forest reserves distributed over different vegetation belts of Switzerland (Fig. 1). Reserve size ranges from 0.6 ha to 245 ha. The research method combined periodical measurements of individual trees ($d_{1.3}$≥4 cm, $d_{1.3}$ = diameter at 1.3 m height) on 299 permanent plots (size 0.1-3.5 ha), and full callipering of all trees in forest compartments (size 2-8 ha). A more detailed description of the methods can be found in Leibundgut (1959) and Institut für Waldbau (1962). The interval between inventories was mostly 10 years. The number of inventories in each plot/compartment ranges from 1 to 7, with a median of 3.

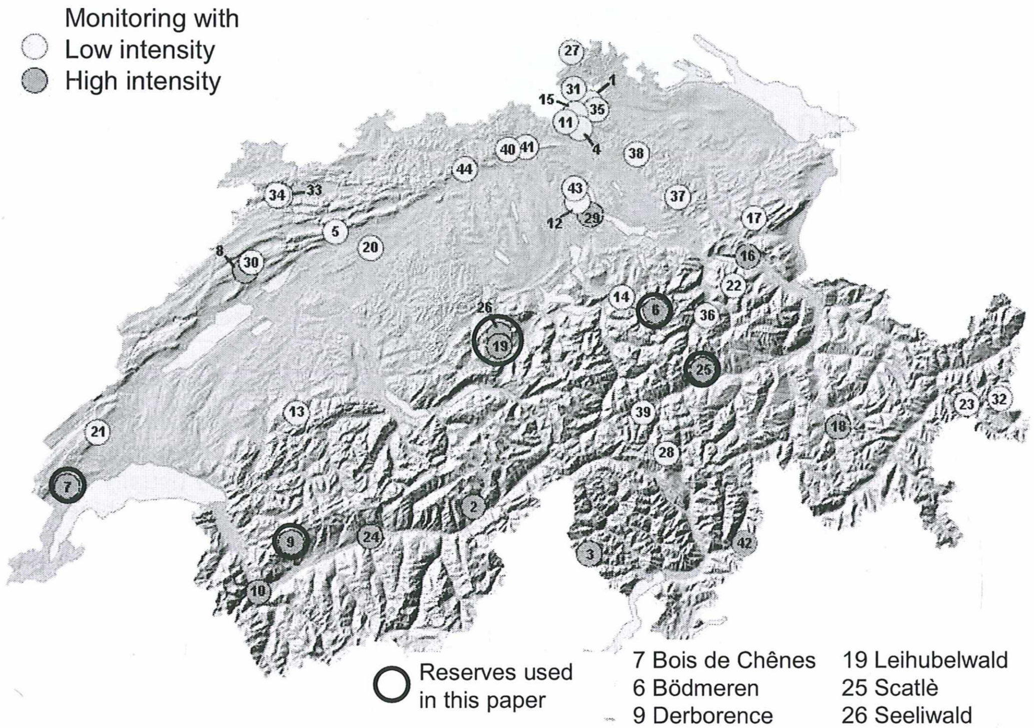

Figure 1: Current network of total forest reserves with monitoring managed by WSL and ETH. The network includes part of the 37 reserves maintained by ETH until 2006. The reserves from which data is used in this paper are shown in

The descriptive data analysis presented in this paper focuses on the six reserves Bois de Chênes, Leihubelwald, Derborence, Scatlè, Bödmeren and Seeliwald (Table 1), with 2 to 11 permanent plots. Plot size ranged from 0.23 to 3.47 ha. The parameters used are the basal area (G, cross-sectional area of all tree stems at 1.3 m height), stem number, tree species richness, and the number of large trees ($d_{1.3} \geq 60$ cm). Rates of change were calculated by using parameter differences between the first and the last inventory available, and dividing them by the time period between these inventories.

Table 1: Site information for the investigated forest reserves.

	Bödmeren	Scatlè	Derborence	Bois de Chênes	Seeliwald	Leihubelwald
Year of establishment of reserve	1971	1910	1956	1969	1972	1972
Forest area in reserve [ha]	5.0	9.1	22.3	83.0	78.6	23.8
Number of permanent plots used / total area [ha]	4 / 4.88	2 / 6.36	2 / 0.98	10 / 7.07	8 / 7.21	11 / 0.99
Altitude [m a.s.l.]	1500	1600-2000	1440-1660	510-570	1355-1550	1080-1270
Mean annual temperature [°C]	3.7	3.6	4.6	8.5	4.0	6.0
Annual precipitation sum [mm]	2300	1550	1490	1200	2000	1770
Aspect		E	NW		NW	E
Geology	Limestone (karstic)	Verrucano	Limestone	Moraines	Flysch	Flysch
Inventory campaigns	1973 1988 2003	1965 1977 1989 2006	1955 1967 1981/82 1990/91	1970/74 1984 1994 2007	1973 1984/85 1996	1973 1983 1995

Results

Several trends were consistent in most permanent plots: a) an increase in basal area; b) a decrease in stem number; c) an increase in the number of large trees, and d) a reduction of tree species richness, particularly in deciduous forests.

Basal area increased by 0.15 ± 0.02 m^2/ha and year (mean ± standard error of mean), while stem number decreased by -9.90 ± 0.12/ha and year. This pattern was found in most permanent plots (Fig. 2). Decrease in stem number was higher in more productive sites (Bois de Chênes, Leihubelwald, Derborence), with means between -15 and -19/ha and year, than in subalpine sites (Bödmeren, Scatlè, Seeliwald), with means between +1 and -3/ha and year. Increase in basal area was also relatively high in two productive reserves (Bois de Chênes and Leihubelwald with means of +0.22 and +0.20 m^2/ha and year, but also in the Seeliwald reserve with 0.18 m^2/ha and year. In the other two reserves, changes in basal area varied from -0.01 to +0.03 m^2/ha and year.

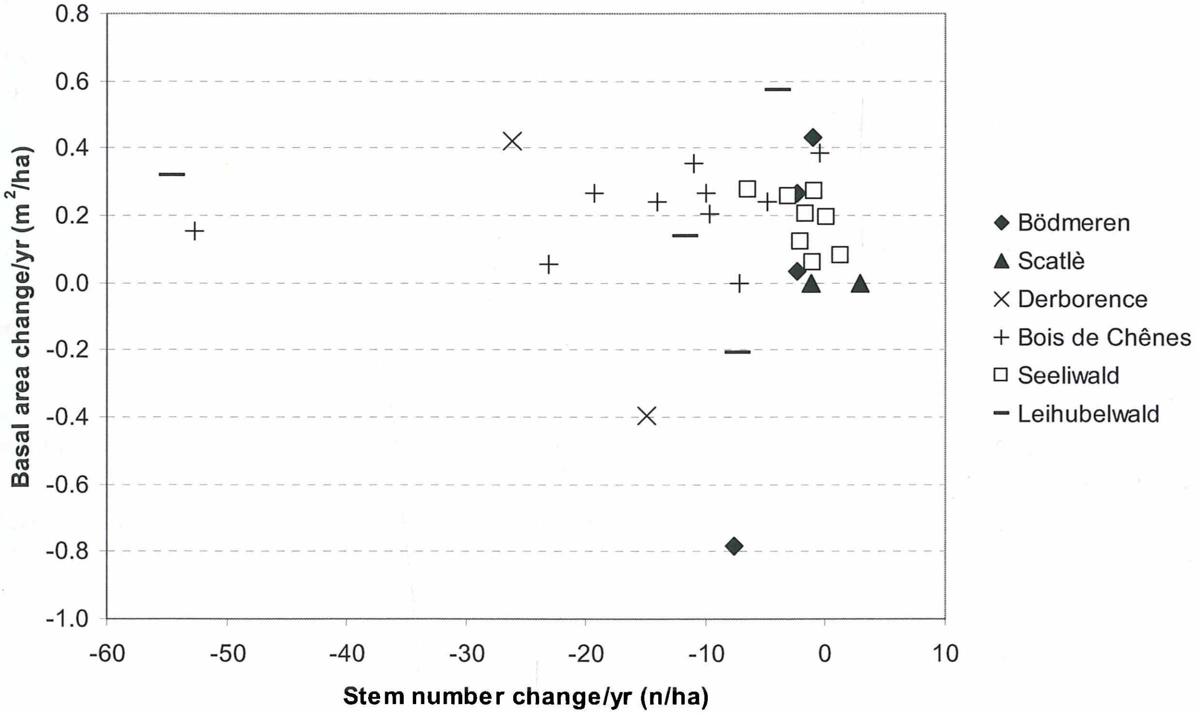

Figure 2: Annual changes in basal area and stem number in 30 permanent plots in Swiss forest reserves. Lower callipering limit for stems was 4.0 cm.

The number of large trees ($d_{1.3} \geq 60$ cm) increased on average by 0.36 ± 0.03/ha and year, with a miniumum of -0.11/ha and year (Derborence) and a maximum of 0.87/ha and year (Leihubelwald).

The number of tree species on each permanent plot varied from 2 to 30. Overall change amounted to -0.046/year. In *Picea abies* forests (Bödmeren and Scatlè), tree species richness remained stable, but decreased by as much as -0.120/ha and year in the lowland forest of Bois de Chênes. Permanent plots in the other reserves had changes between +0.014 and -0.022 species/year.

Discussion

The trends in stand structural attributes found on 30 permanent plots during time periods of 22 to 41 years are in line with what would be expected in early- to mid-successional stages ('optimal phase', LEIBUNDGUT 1982, or 'stem exclusion' to 'understory reinitiation' stages, PICKETT & WHITE 1985): Basal area and the number or large trees increased, and stem numbers increased on average and on most plots. Moreover, the growing stock is in most permanent plots below the levels known from studies in eastern European old-growth forests (KORPEL' 1995). The tree species richness decreased, in particular in shade-intolerant species (HEIRI et al. in press), which suggests that species promoted by former management are increasingly shaded out in the absence of disturbance. Disturbances were rare so far in the permanent plots. In the sample presented here, they occurred in Derborence (several plots, but partly after the last inventory), Bödmeren (one plot) and Leihubelwald (one plot).

The data have only partly been exploited for scientific questions. We are currently checking if the patterns presented in this paper hold for data from all permanent plots and compartments, and analyzing the differential behavior of tree species (HEIRI et al. in press) and tree mortality (WUNDER et al. 2007), as process creating dead wood.

The monitoring methods originating from the 1950s need to be completed to provide answers to current questions. Therefore, we refocused the research program in reserves in 2006, for instance to include an assessment of dead wood and habitat structures such as tree hollows and broken crowns (BRANG et al. 2008), as indicators for organismic diversity. The direct assessment of this diversity seemed, in a countrywide monitoring project with limited resources, unfeasible. Meanwhile, the value of the original data from increases with each inventory.

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