Summary

Butler Manning, D. (2007): Stand structure, gap dynamics and regeneration of a semi-natural mixed beech forest on limestone in central Europe – a case study.

Freiburger Forstliche Forschung (in press)

In 1999 the Institute of Silviculture of the University of Freiburg began a long term investigation into the natural dynamics of central European beech forests. The opportunity for the study arose when the then director of the institute, Prof. Dr. Jürgen Huss, identified the ideal site for research of this kind in the newly founded Hainich National Park, on a site with a largely natural structure and indications of natural dynamics.

The Weberstedter Holz, a 300 ha large mixed beech forest located on the southern end of the Hainich mountain range in Thüringen, has effectively been completely unmanaged since the middle of the last century. During that time the forest has acquired a largely natural character.

For decades the Weberstedter Holz and the forests around it served as a buffer at the margins of land used for military training purposes, first by the Soviet army and subsequently by the Nationale Volksarmee of the German Democratic Republic. As a consequence, use of the forests was kept to a minimum and access was greatly restricted. Historically, too, the forests of Hainich were spared the far reaching changes to the landscape occurring throughout central Europe due to the remoteness of the location and its unsuitability for agriculture.

A complete inventory of an area of almost 30 ha was carried out between the years 1999 and 2000, with almost 15 000 living trees mapped and measured. The site has been set up to serve as a permanent observation post to chart the development of a mixed beech forest left entirely unmanaged.

The hypotheses underlying the study were that:

- storms and other catastrophic events only rarely lead to larger gaps in the canopies of beech dominated forests,
- continuous canopy cover in natural forests favours beech at the expense of the other, noble broadleaf species otherwise present on calcareous sites, and
- modern natural forest management concepts further promote the dominance of beech, and as a result these forests don't exhibit rich mixtures.

The objectives of the study were:

- to determine the effects of more than 5 decades without management on the tree species composition and structure of a beech forest within the species' optimum range,
- to study the impact of natural disturbances on the canopy and the structure of an unmanaged beech forest, and
- to chart the development of young tree growth in these natural gaps, and to ascertain the impact of unregulated browsing on the regeneration process.

The study presented herein was divided into 3 parts, corresponding to the underlying hypotheses and study objectives. The results of each part are presented briefly in the following.

1) The stand structure of the Weberstedter Holz

The research site hosted 13 different broadleaf species. Beech was clearly dominant, accounting for 90 % of the total tree number, but ash, hornbeam and sycamore were also present in moderately large numbers. The stocking density across the site was high with 537 trees /ha. The diameter distribution followed a negative exponential pattern, as deemed characteristic of both selection and natural beech forests, i.e., there were exceptionally large numbers of trees with a DBH <15 cm, declining dramatically in number as the diameter increased. The largest tree present on the site was a huge ash with a DBH of 126 cm, and a height of 47 m. The average canopy height was 34 m, but isolated beech achieved heights of 42 m. The basal area was high at 36 m^2 /ha, and the volume exceptionally large at 630 m^3/ha, and in excess of 2 000 m^3 /ha locally. A comparison of the stocking density, basal area and volume across the site demonstrated its great heterogeneity.

Despite their lower proportions in the stand relative to the total tree number, ash accounted for 16 % of the total basal area, and sycamore and Norway maple a further 8 %. These high values indicated the dominant position these species assumed amongst the canopy trees. The analysis of the stand stratification revealed that the admixed species were essentially absent below the canopy, however. Only hornbeam exhibited a degree of shade tolerance great enough to facilitate its survival beneath the beech canopy, but even it was absent from the smaller size classes. This highlighted the difficulties experienced by the admixed species regenerating where there is no management to promote their survival.

The results of the analysis of the stand structure revealed a species richness untypical of the remnant beech virgin forests of eastern and south eastern Europe. This was a product of the coppice-with-standards origins of the stand. In most other respects the structure of the Weberstedter Holz resembled that typical of the remaining beech virgin forests, however, namely a very heterogeneous make-up, multiple storeys, large dimension trees, and extraordinary standing timber volumes and high dead wood levels.

2) The natural gap dynamics of the Weberstedter Holz

The gaps in the canopy of the Weberstedter Holz were recorded employing 3 different gap definitions commonly cited in the literature. The study revealed great variations in the results obtained depending on the definition employed, and highlighted the need if not for standardisation in gap studies, then at least for transparency in the methods.

The gaps study showed that the proportion of gaps in the canopy over the 3 recording periods was very low, ranging between 2-4 % of the total area. A slight increase in the gap area was observed between the years 2002 and 2005, but the average gap size remained largely constant at between 110-130 m^2. The majority of the gaps were even smaller, however, between 50-100 m^2. The largest gap observed was 800 m^2, but this shrank to 600 m^2 over a 32 month period. The study revealed that whereas some gaps increased in size, others declined or even closed again within a relatively short period of time.

Often the gaps in the canopy were already partly occupied by advance beech regrowth, providing little opportunity for the establishment of light demanding species. A large scale collapse of the stand, and a reversal to a pioneer succession stadium was not evident.

3) Regeneration in the Weberstedter Holz

Beech, ash and the *Acer* species revealed a high capacity for regeneration, both under the canopy and in the gaps in the Weberstedter Holz, corresponding with the reputation of calcareous beech forests for abundant tree regrowth. The other species found in the canopy were clearly not regenerating, however. Seedling numbers under the canopy

were 35 000 /ha, compared to approximately 70 000 in the gaps. The height growth of both beech and ash stagnated at approximately 50 cm beneath the canopy.

Growth in the gaps was slightly better, but only where there were fences. Ash seedlings present in the gaps clearly demonstrated the positive effects of fencing within a matter of 3 years, and beech was beginning to profit after 4. The *Acer* species also profited from fencing as much as ash, but established in the gaps in lower numbers due to the increased competition from a ground vegetation layer undisturbed by trampling. Unlike the beech and ash, the *Acers* also demonstrated a capacity to grow under the closed canopy when protected by fences, demonstrating extreme early shade tolerance. Few of these seedlings exceeded 1 m in height, however, and it remained to be seen, therefore, whether this would continue indefinitely.

The light intensities in the natural gaps were also very low, with possible implications even for seedlings in fenced gaps once their early shade tolerance subsides.

Conclusions

The studies in the Weberstedter Holz have only just begun, and as such it was too early to either accept or reject with any degree of certainty the hypotheses proposed at the outset. The developments observed so far would appear to lend each of them credence, however.

Over 50 years of natural development of the Weberstedter Holz have seen the admixed species disappear entirely from the lower levels of the stand. Despite good representation in the canopy layer, and exceptionally high regeneration rates, neither ash nor sycamore have established successfully in very many years. Even the shade tolerant hornbeam has failed to regenerate.

The gaps study revealed that the gaps occurring naturally in the canopy to date were very small, and that large gaps were rare. Even the biggest gaps were smaller than the sizes recommended for the establishment of either sycamore, ash or oak. And rather than expanding with time, it was observed that in many cases the gap sizes actually declined. This decline in size was partly the result of crown expansion by edge trees, but also through filling in by subcanopy beech trees. This left little opportunity for light demanding noble broadleaves regenerating in freshly established gaps to persist in the stand. The large numbers of subcanopy trees present across the site would appear to rule out the future creation of significantly larger gaps.

The hypotheses cannot be conclusively confirmed for 3 main reasons:

- The first is the age of the stand. A number of the standards from the coppice-with-standards management of the 19th century still remain. It remains to be seen whether these will all come to the end of their natural life spans within a relatively discrete period of time, or whether they will continue to perish gradually.
- Secondly, the high proportions of the light crowned ash and sycamore in the canopy may have facilitated the successful establishment of large numbers of subcanopy trees waiting to fill any gaps that do occur. Under a pure or almost pure beech canopy this may not have been possible.
- The final factor was highlighted by the fencing experiment. The hypothesis that an absence of management leads to the loss of admixed species could not be confirmed because with no fencing prior to the year 2000 it is impossible to gauge the effect that deer may have had on the regeneration of the stand over years.

In conclusion, therefore, the results of this study served to highlight that a huge reduction in game levels is essential for the successful establishment of the noble broadleaf species. Furthermore, they suggested that natural gaps created in the canopy of beech forests are too small to facilitate the establishment and growth of the noble broadleaf species. Only in exceptional cases are sufficiently large gaps likely to arise

naturally, and contrary to normal management practices it would appear these may subsequently decline in size rather than expand, which will have implications for growth rates and also timber quality.

Most importantly perhaps, the foundations have been laid for the long term study of the natural dynamics of an ecosystem that still remains largely unknown. This is in spite of the fact that beech is the single most important tree species in the vegetation of central Europe. The size of the research site, the comprehensiveness of the data and the degree of naturalness evident in the Weberstedter Holz currently, far more advanced than in many of the German beech forest reserves, make this an enormously valuable research asset.