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SILVICULTURE IN MOUNTAIN FORESTS

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SUMMARY

An abstract of 10 years of silvicultural research in the mixed mountain forests of the Bavarian Alps is presented. The study evaluates the influence of different silvicultural systems (clear-cutting, gap cutting, heavy and light shelterwood cutting, no treatments) on:

- ecological characteristics
- resistance of residual stands against storm
- seed production
- density of regeneration
- development of regeneration
- biological productivity.

The study indicates clearly, that the forest type investigated, which is characteristic for the whole northern ridge of the Alps, regenerates abundantly with all silvicultural systems, if applied carefully. The "minor" species of the old stand, maple, fir and yew, are overproportionally represented in the regeneration layer. However this process of regeneration is so heavily hampered by browsing of deer, and to a much lesser extent by grazing cattle, that almost only the least browsed species, Norway spruce, is able to survive the regeneration process. Similarities with forests in other mountainous regions of the world are shown.

INTRODUCTION

Forestry in mountainous regions has to regard very strictly, that production and utilization of forest products has to be achieved without jeopardizing the protection potential of the forest cover and without changing its aesthetic properties too much. The range of silvicultural means to achieve such goals is fairly wide. We will try to report on the results of a comprehensive research project by which it became possible to evaluate the characteristics of different silvicultural systems applied on mountain forests of the Bavarian Alps.

FIGURES 1 and 2 point out the geographical, ecological and silvicultural background of the research area which is fairly representative for the whole northern ridge of the Alps, especially the portion of it located in Bavaria. As is evident from the figures, there is a clear stratification in the forest cover according to elevation, with the typical spruce-fir-beech-maple mountain forests playing the prominent role. The whole of the region has been heavily influenced by man-kind for centuries. At present, several of the centuries-old uses such as grazing and forestry are still practised, whereas the new ones such as tourism and deer pressure, as a consequence of an increasing demand for hunting, have undergone a tremendous development over the last hundred years. Tourism is by far the most important enterprise for almost the whole of the Alps.

THE PROBLEM

The main principle of silviculture in the Bavarian Alps was established long ago, as expressed in the following quotation:

"Prime principle of silviculture for the Bavarian Alps is the maintenance and the re-establishment of mixed stands of spruce, fir and beech, because of their higher resistance against snow, ice and other hazards (insects) in comparison to pure spruce." Bavarian State Forest-Administration, 1861.

The essence of it applied to the present time can be summed up into the following postulates:

1. Maintenance or re-establishment of natural species composition, mainly beech-fir-spruce-maple and others.
2. "Slope stability maps" indicate for every given site the advantages or disadvantages of silvicultural measures to be applied, and risky ones to be excluded. The most important criteria for this type of mapping are soil type and steepness.
3. Maintenance of the original (autochthonous) tree populations. (No introduction of genetically altered tree stock).
4. None or only restricted use of exotic tree species.
5. Avoidance of clear cuts; application of long-term silvicultural treatments.
6. Application of selection type of silviculture wherever possible. Many types of protection forests are considered to require this type of silviculture.

In order to find out whether these principles have been achieved, we carried out an inventory of the high elevation forests in the "Werdenfelser Land" region near Garmisch-

Fig. 1
NATURAL CONDITIONS FOR FORESTRY IN THE CHIEMGAU - ALPS, IN THE SOUTH - EAST OF BAVARIA

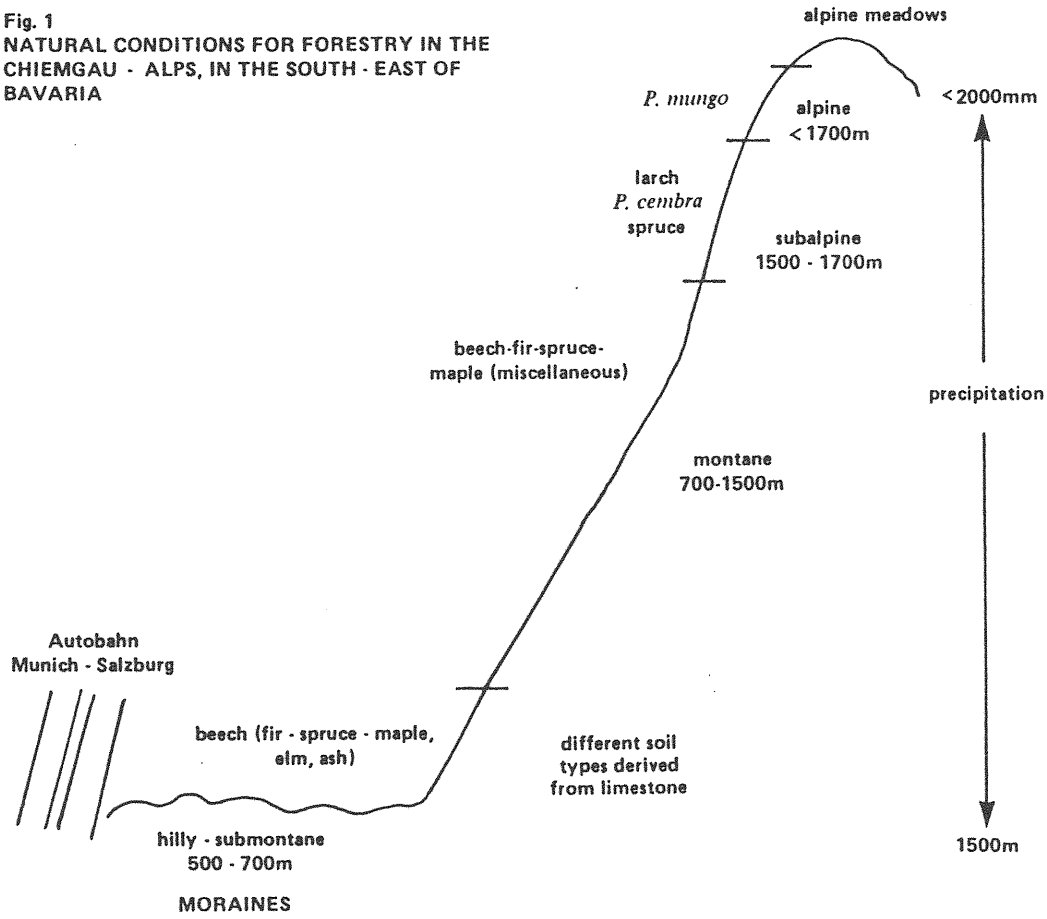
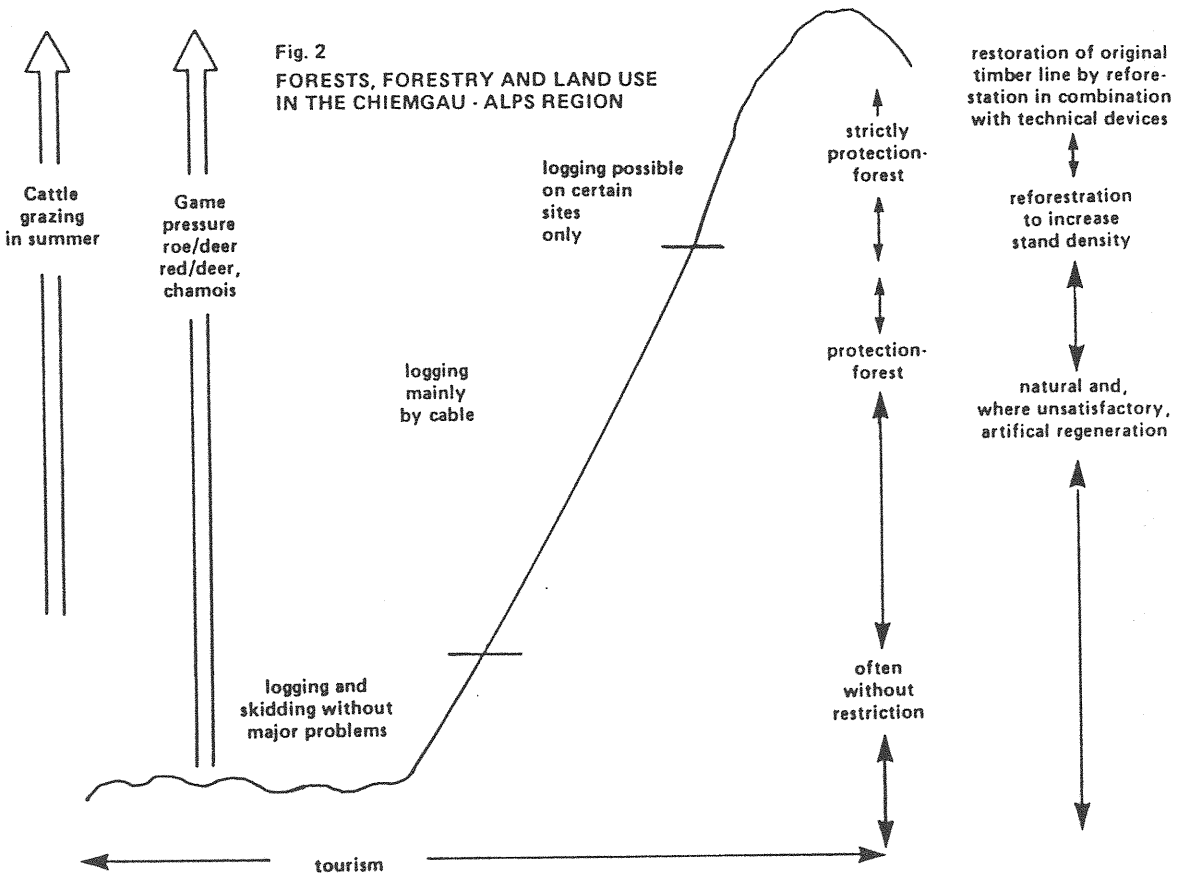


Fig. 2
FORESTS, FORESTRY AND LAND USE IN THE CHIEMGAU - ALPS REGION



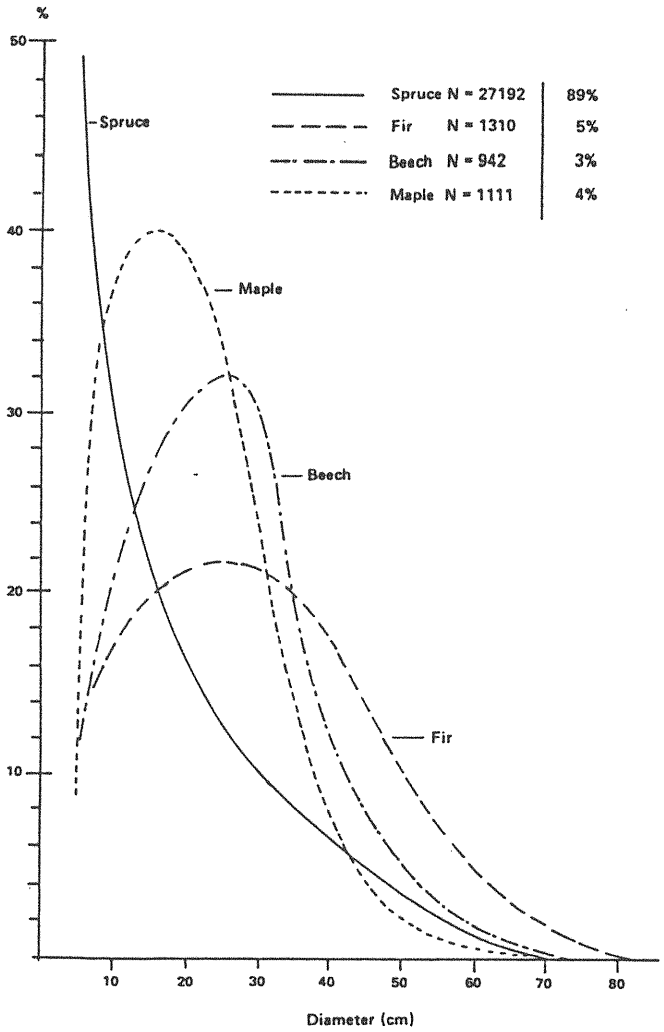


FIGURE 3. Frequency of diameters Inventory of the "Werdenfelser Land" region.
Area investigated : 4 600 ha
Altitude : > 1 300 m a.s.l.
(Burschel, Low, Mettin, 1977.)

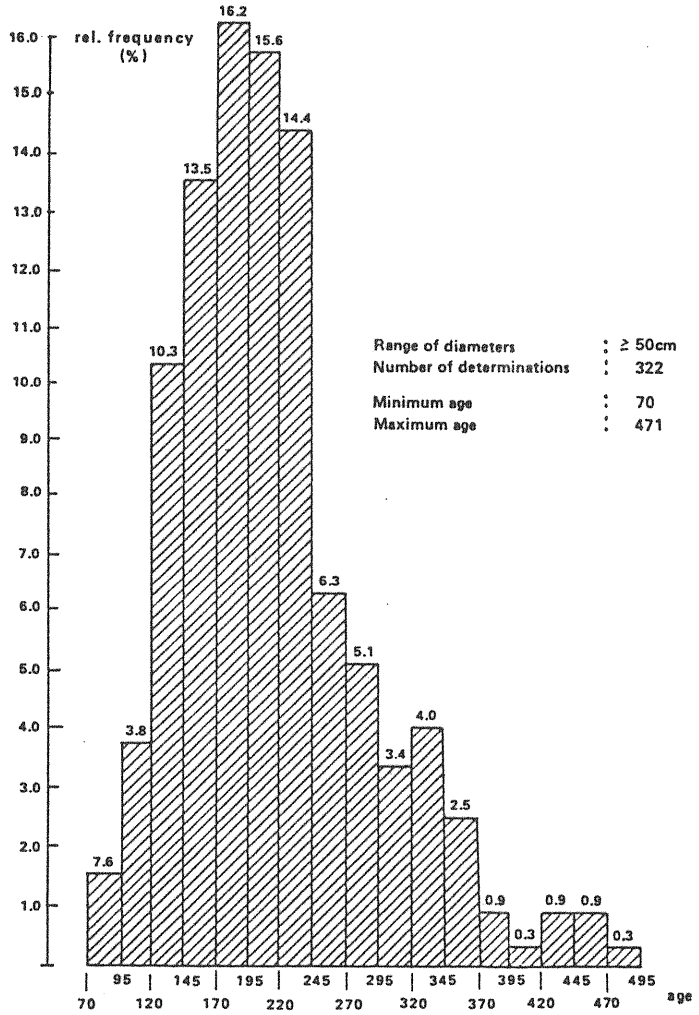


FIGURE 4. Age Distribution of Trees more that 50 cm dbh (Inventory "Werdenfelser Land".)
(Burschel, Low, Mettin, 1977)

Partenkirchen. The results are presented in FIGURE 3. They clearly indicate that while the original mixture is still present in the larger diameter classes, all species except for spruce are diminishing in number as diameter decreases. As a matter of fact, the younger components of the forests surveyed, consist almost exclusively of spruce. An abrupt and dramatic loss of other species is taking place. (FIGURE 4 is only presented to show that these high elevation forests cannot be compared with managed forests of lower regions; they are relatively open alpine pasture forests, containing some very old trees).

After having established the results documented here, an additional survey was conducted of the very early stages of forest development. These are the plants of less than 20 centimetres height, which normally remain invisible in the ground vegetation. Surprisingly enough, we found a large number of these seedlings and saplings, numbering seldom less than 25 000 per ha. Yet another major surprise was the presence of all species present in the higher diameter classes of the old stands, reappearing in these early regeneration stages. Even trees such as Sorbus aucuparia or sycamore (Acer pseudoplatanus) were found in large numbers. They very likely get spread either by birds or by their winged seeds, even with few or distant seed trees available.

After the findings showed the loss of mixture in the old stands, which was confirmed by inventories covering lower parts of the region, we decided to establish a comprehensive experiment to find out the reasons for such a development in forest composition. This is of particular interest as it is clearly in disaccordance to the old silvicultural aims which have remained constant.

THE EXPERIMENT

In 1976, 25 research plots were established in the eastern part of the Bavarian Alps (forest districts of Ruhpolding and Siegsdorf). The details of the layout of these comprehensive experiments have been published on several occasions, and need not be mentioned here. The experimental design evaluated the most frequent and important silvicultural systems. Presented here are some of the results obtained after 10 years of study. (This experiment has now been under observation for 15 years).

Ecology

In TABLE 1 the influence of silvicultural systems on some ecological factors is documented. As expected, light and radiation reaching the forest floor are determined by canopy closure, with relatively small but biologically important improvements by heavy shelterwood cuttings. It is evident that even in the gaps (circular cuttings, 30 metres in width), light

intensity is only a quarter of that on clearcuts (1 ha). The precipitation reaching the ground increases sharply with the opening up of the canopy, as interception rate decreases. Since the rainfall is generally high, such gain will be of biological relevance only in dry years, which here are not very frequent. A very important aspect of mountain forestry is the modification of the activity of snow on the ground. In addition to this, snow becomes more and more compacted during the winter season (mainly by the thawing and refreezing processes of the day and night cycle), and finally shows a density considerably higher than the one attained under canopy.

Climatic parameters	Control	Heavy shelterwood cutting	Gap cutting	Clear-cutting
Radiation %	9.4	22.9	-	100
Rel. light intensity %	7.7	25.1	73.2	100
Precipi-tation, mm (summer 1977)	715	800	830	950
Days with snow cover > 1 cm (winter 78/79)	97	102	125	132

TABLE 1. Some ecological characteristics of different silvicultural treatments (Berthold, (1980); Mayer, (1979)(1981))

As a consequence, on the open sites there is not only more snow, but it also lasts a month longer than under the canopy. This finding is important for two reasons:-

i) In the open sites, the danger of infection of snow covered spruce plants by Herpotrichia nigra increases,

ii) The probability of damage by snow movement to young plants increases.

Within the altitudinal range of our research area (700 - 1 200 m a.s.l.), until now none of the above mentioned problems have been severe, but they represent the prime danger for high altitude regeneration measures, whether natural or artificial.

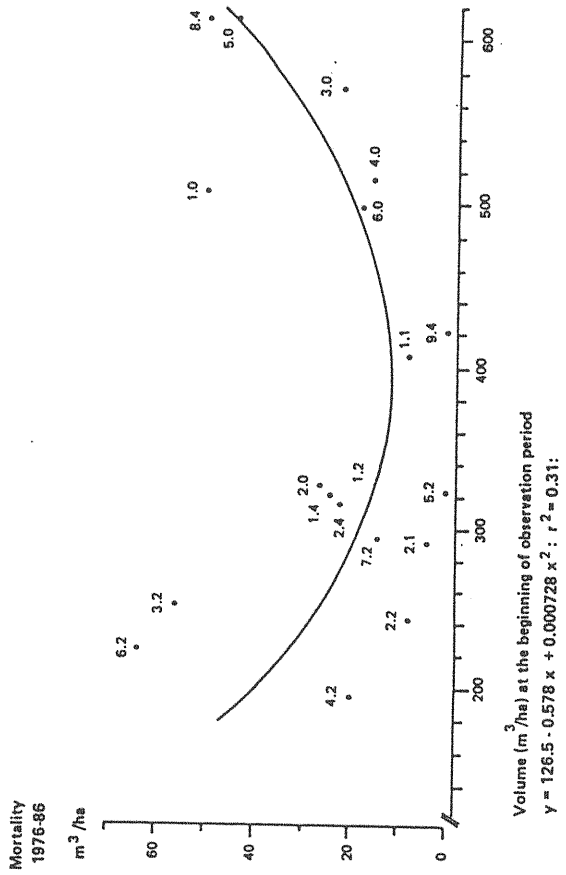


FIGURE 5. Mortality rate in standing crop (m^3/ha) in relation to volume at the beginning of observation period. Figures after decimal point correspond to type of treatment being:- 0 = control; .1 = light shelterwood cutting (30% of standing crop taken out); .2 = heavy shelterwood cutting (50% taken out) .3 = clearcut; .4 = gapcutting. (Figures before decimal point indicate internal plot number). (Mosandl, (1990)).

Some Reactions of the Old Stands to Regeneration Cuttings

Within the observation period, the old crop yielded a considerable volume of timber, which is sufficient to justify forestry in the region of the mixed mountain forests. What is interesting within the context of this presentation is the development of mortality in relation of the silvicultural systems applied.

FIGURE 5 indicates a clear minimum of losses by mortality in the range of stockings (300-500 m^3/ha), which corresponds to light shelterwood cuttings. It increases considerably when the stands are maintained very dense, and increases as well when they are markedly opened by heavy shelterwood-cuttings. In the first case high density leads to considerable losses by competition and in the second losses by wind-throw increase severely. Both findings are of great relevance for the evaluation of the silvicultural systems to be applied.

Seed Production

One of the most important aspects of natural regeneration processes is the seed supply that can be expected. Our results (troublesome and expensive to obtain) are presented in TABLE 2. They indicate clearly that there is an abundant seed production in the mountain forest studied. Within 10 years, all the tree species have produced sufficient seeds to ensure regeneration. The intervals were not too long between the heavy seed crops, with lighter seed crops occurring in between. Only the frequency of seed years of beech was lower. With regard to the relatively reduced number of beechnuts observed, it should be taken into consideration that the number of seed trees was small. Summarizing the potential of seed production, it can be stated that the old stands are vigorously producing seeds and that the seed density on the ground - with a viability of about 30% - is absolutely sufficient for every tree species to satisfactorily regenerate.

Density of Regeneration

As can be expected from the seed data, regeneration is established abundantly, without any delay. TABLE 3 shows this clearly. There was no silvicultural system which would not have led to a full stocking of regeneration, with the shelterwood cuttings giving by far the best results. These are obtained by a combination of good seed supply and relatively good light conditions, giving excellent possibilities for the young plants to get established. It is interesting to note that all tree species are present in this process, with spruce by no means predominant. Such a role has been achieved by maple, which plays a minor role in the old stand. It is worthwhile mentioning in this respect that the column "others" in TABLE 3 contains species such as Sorbus aucuparia, Sorbus

aria, ash, willows. Even yew (Taxus baccata) occurs on some plots - which is spread by birds.

Silvicultural Treatment	Spruce	Fir	Beech	Maple	Sum
control	4.146	2.178	605	1.789	8.718
heavy shelterwood cutting	2.746	1.254	461	1.611	6.072
gap cutting	4.720	360	592	583	6.255
viability %	31-36	27-32	35-48	31-44	-

TABLE 2. Number of seeds (thousands per ha) during 1976-1986 (Veltsistas, (1980); Mosandl, (1990))

Silvicultural Treatment	Spruce	Fir	Beech	Maple	Others	Sum
control	8	36	27	83	6	160
heavy shelterwood cutting	53	90	23	321	8	495
gap cutting	3	8	8	55	3	96
clear cut	1	5	2	68	1	77

TABLE 3. Density of natural regeneration (thousand per ha) at the end of the 10 year observation period. (Mosandl, (1990))

Development of Regeneration

Now one has to query the reasons why stands so apparently readily regenerated, are losing the original mixture, with only spruce and perhaps some beeches left (FIGURE 3). The answer can be derived from FIGURE 6. The experimental design of our

research project, allows on each plot a comparison of fenced and unfenced areas. Such a comparison is made for fir for example in FIGURE 6.

Four outcomes are derived fairly clearly from these graphs:-

- Survival rate of plants is closely correlated to fencing and light supply. Without the fence, the survival rate remains very low, showing no relationship with the density of canopy. With the exclusion of deer (game) and cattle, the survival rate increases with opening up of the canopy, reaching maximum values in the range of heavy shelterwood cutting.

- Inside the fence, regenerated plants remain practically undamaged, while with free access of browsing animals, the damage increases with better light conditions. This is due to the small plants on the darker plots being apparently much less attractive to deer and cattle than the vigorously growing plants on the clear-cut plots.

- The top height of young plants increases slowly with improved light conditions, showing full vigour only under open situations. This relationship between height growth and light intensity is modified by browsing. The corresponding suppression is evident but small in dark situations and with heavy shelterwood cutting. It becomes drastically evident in the open situations, where the fenced plants have reached twice the height of the unfenced browsed ones. What makes matters worse is that young firs accessible to deer do not increase in height as long as browsing goes on.

- Hence the conclusion can be drawn that browsing is the main obstacle for the maintenance of the mixed mountain forests, with all species affected except spruce.

Silvicultural Systems and Biological Productivity

The investigation carried out into the dynamics of mixed mountain forests has made it possible to develop some insights into how the productivity of such biological systems is influenced by silvicultural measures. TABLE 4 contains the results.

The input-output balance leads to the following considerations:-

- As a consequence of high mortality on the dense control plots the excess of input over the output values is so small that the whole system is approaching a steady state equilibrium. The regeneration though very dense contributes almost nothing as far as production is concerned.

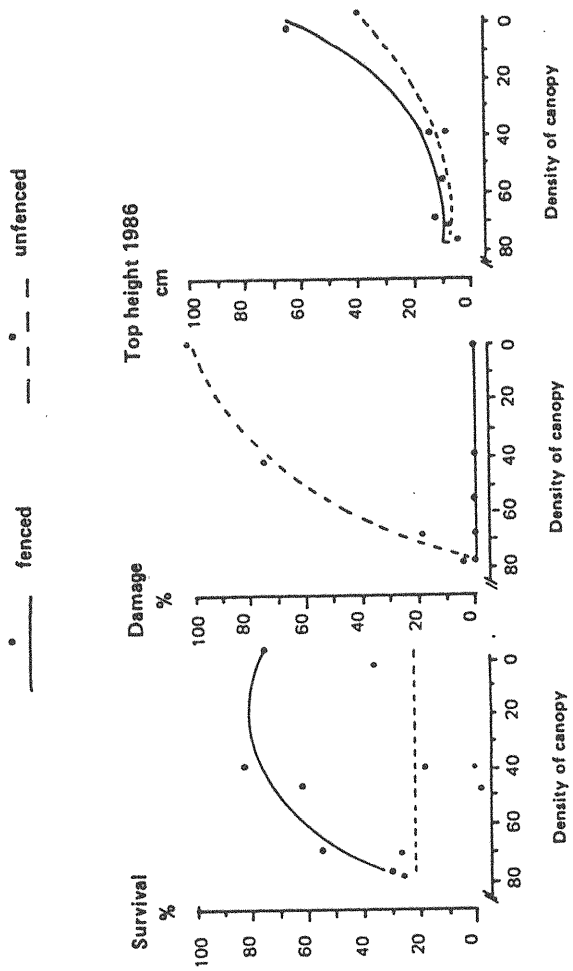


FIGURE 6. The effect of canopy density % and fencing on the development of fir plants. (all measurements after 10 years of observation, 1986) Mosandl, 1990.

- After heavy shelterwood cutting, a marked excess of input over output has been achieved, mainly as a consequence of minimising the natural mortality of trees. The entire increment is accumulated. The system changes from a steady state, to a situation of aggregation. The very dense regeneration, because of the improved availability of light, attains considerably more production, (more that 10 times as much as on the dense control plot), which however still remains far from the corresponding production values of the old stand.

- Under full light conditions on the clear cut, the forest regeneration within a few years has achieved production rates that come close to the ones observed after shelterwood cuttings for both old stand and regeneration. Regeneration biomass production is in any case considerably higher than on the control plots, resulting in fast accumulation of biomass.

- The dramatic influence of browsing on the forest regeneration process can be ascertained from the comparison of fenced and unfenced situations on the clear cut. The impact of animal browsing is so severe that the bio-production is almost completely shifted from regeneration to ground vegetation, which does not accumulate biomass.

CONCLUSIONS

- A wide range of silvicultural measures could allow the maintenance or the re-establishment of mixed mountain forests in the Bavarian Alps.

- The seed bearing potential of the old stands is considerable, and sufficient to ensure a complete and dense regeneration of all tree species.

- The development of natural regeneration correlates strongly with the density of canopy, being most vigorous in gaps and clearings, but considerably reduced in growth under canopy, even under fairly open canopy such as heavy shelterwood cutting. Where natural regeneration fails, or ground vegetation develops very rapidly, planting should be immediately carried out as a substitute for natural regeneration.

- As compared to dense stands, shelterwood cuttings will increase the biomass as well as volume productivity.

- Heavy shelterwood cutting tends to reduce the stability of the remaining stand against storm. A slow progress, beginning with low intensities of cuttings (light shelterwood cutting) should be preferred.

	Control	Heavy shelterw. cutting	Clearcutting fenced	Clearcutting unfenced
I Increment Wood	+ 2.449	+ 1.899	0	0
N Increment Leaves	+ 2.659	+ 1.569	+ 191	+ 191
P Seeds	+ 16	+ 10	+ 1	+ 1
U Nat. Regeneration	+ 3	+ 38	+ 1.594	+ 60
T Ground Vegetation	+ 20	+ 778	+ 834	+ 2.214
Sum	+ 5.147	+ 4.394	+ 2.620	+ 2.466
O Mortality				
U In old				
T stand	- 1.881	- 324	+ 2.620	0
P				
U Litter	- 2.659	- 1.569	- 191	- 191
T Ground Vegetation	- 20	- 778	- 834	- 2.214
Sum	- 4.560	- 2.671	- 1.025	- 2.405
Input-Output	+ 587	+ 1.623	+ 1.595	+ 61

TABLE 4. Input-Output Relation of above-ground biomass (kg/ha), influenced by silvicultural measures (Mosandl, 1990).

- Because of the excellent development of the regeneration in gaps and on clear cuts, the biomass production under such conditions soon attains the level of old stands.

- The process of natural and artificial regeneration is severely inhibited by deer browsing and - to a far lesser extent - by cattle grazing. If deer populations cannot be reduced considerably, the maintenance of the mixed

mountain forests will not be possible. Especially fir, maple and all minor species will disappear, leaving spruce and some beech only.

FINAL REMARKS

These findings and conclusions lead to some general considerations. The mountain forests studied are able to regenerate and to respond to different silvicultural treatments. The failures observed on large areas to reach the silvicultural goals of maintaining the mixed character of the stands, stem exclusively from human impacts. In this case the high densities of deer kept for hunting purposes is the only major factor inhibiting the development of the regeneration. (From a separate study we know that the impact of cattle grazing is of clearly minor importance).

In this respect the Alps do not represent a special case. Studies carried out by the authors in other mountainous regions of the world, led to similar results. FIGURES 7 and 8 show the situation in the Western Himalayas and the Andes of Chile. In the former case a manifold and impressive forest cover, stratified according to elevation, would be very reactive to many types of silvicultural treatments. However regeneration processes are completely interrupted by very intensive cattle, sheep and goat grazing, with permanent normally small scale cuttings gradually opening up and often degrading the forest.

The latter case differs from the one described for the Bavarian Alps and the situation in the Himalayas. In vast areas of the southern Andes, beautiful broadleaved natural forest (Nothofagus), with some Araucaria and Podocarpus species as conifers mixed in, have been and are still heavily exploited for timber and frequently burnt afterwards. Here in a region of luxuriant productivity, large areas are heavily devastated by crude exploitation measures without any consideration of the regeneration requirements of this type of forest.

By these examples, which cannot be further detailed here, it is intended to show that mountain forests in many parts of the world are in a reactive and vigorous stage of development. On many sites they can be managed by applying cautious silvicultural systems if other constraints, normally of a socio-economic or purely economic kind, can be overcome. Man, not the forest nor well planned forestry is the problem!

Fig. 7
FOREST, FORESTRY AND LAND USE IN THE WESTERN HIMALAYAS

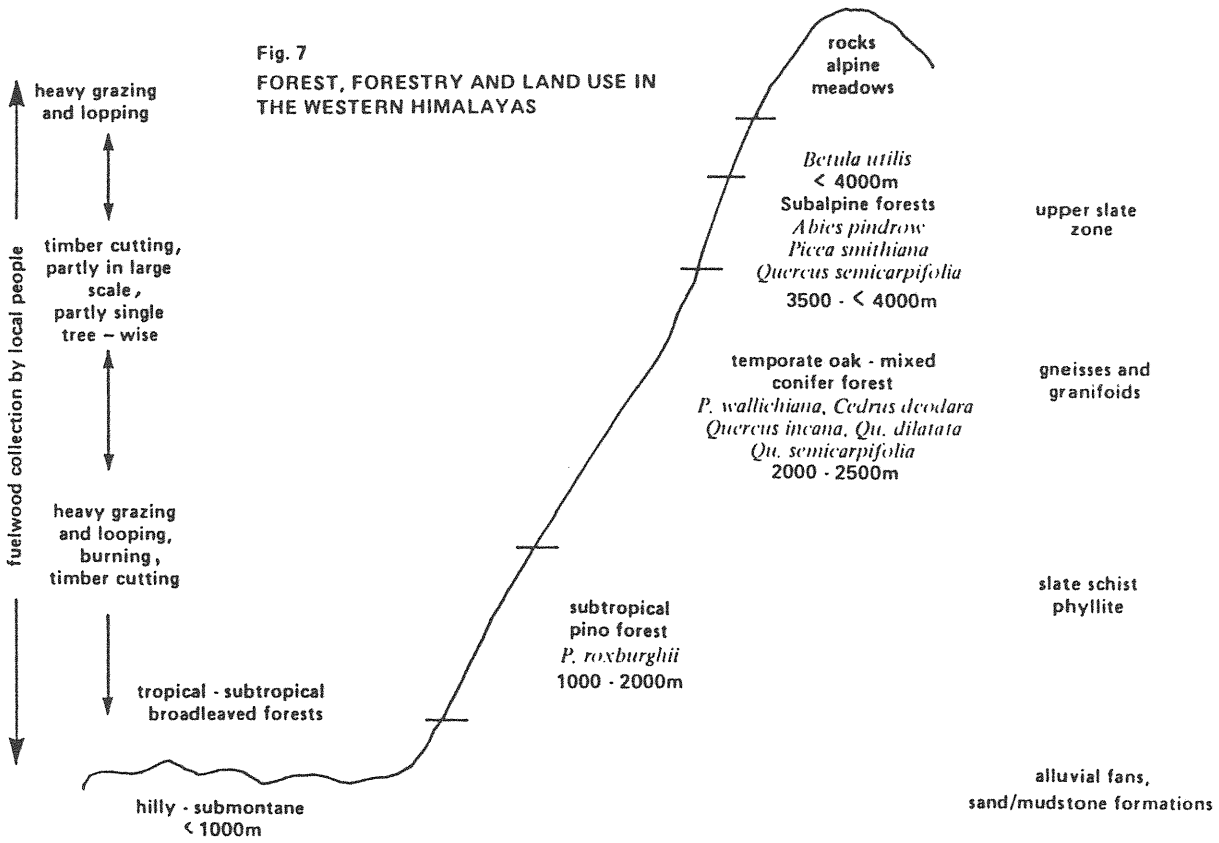
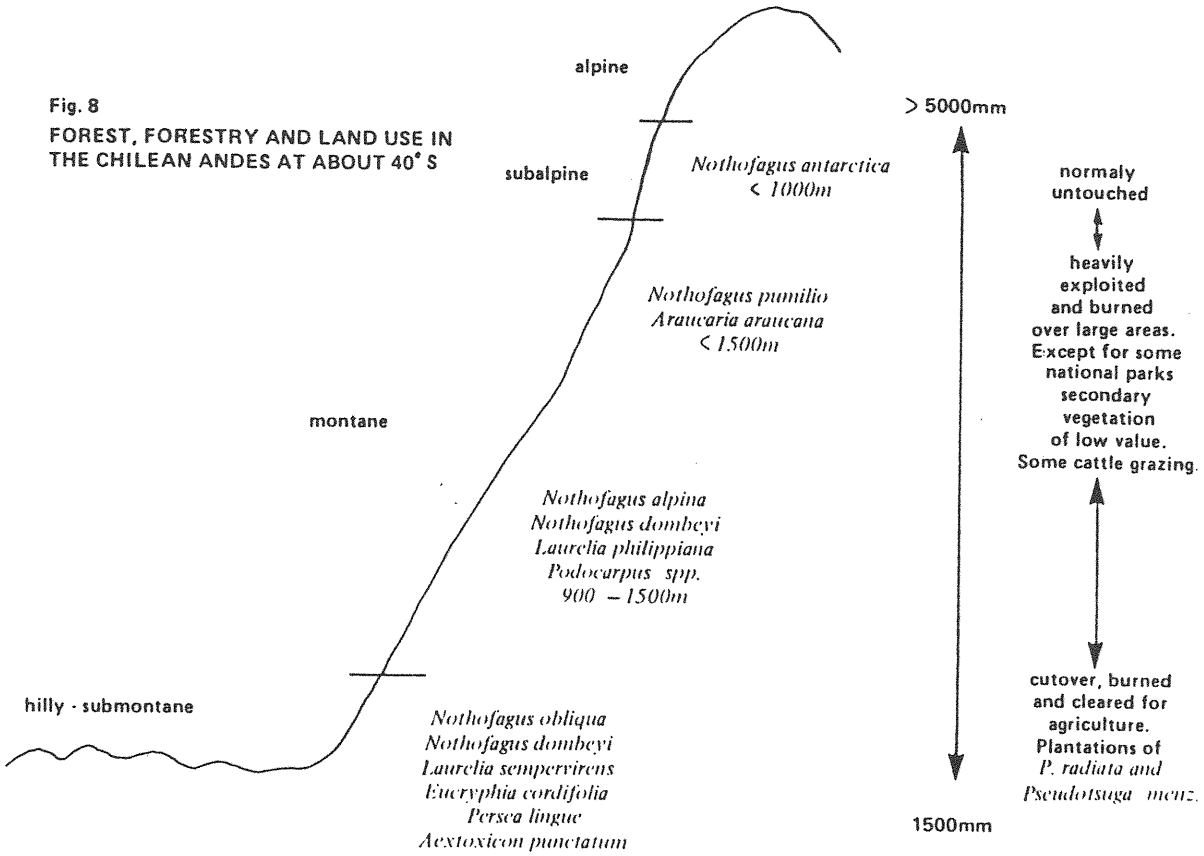


Fig. 8
FOREST, FORESTRY AND LAND USE IN THE CHILEAN ANDES AT ABOUT 40° S



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DISCUSSION FOLLOWING THE PRESENTATION BY P BURSCHEL

Mayhead : What species do you call maple and mountain ash?

Burschel : Sycamore and Sorbus aucuparia.

Malcolm : You have given a clear description of how to develop management systems. Have you any idea how forests functioned prior to interference by man?

Burschel : Gaps were created by winds coming from outwith the prevailing direction. (In Bavaria's case from the south). These strong winds blew the older and weaker trees down and natural regeneration was waiting to take advantage.

Voysey : Does atmospheric pollution have an effect on the shelterwood system?

Burschel : This is a difficult question. It does not appear to affect the natural regeneration but results are not clear.