ZONATION IN THE FOREST RESERVE POLJSAK *

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1. GENERAL DESCRIPTION

1.1. Geographic situation

The forest reserve Poljsak in Slovenia - Jugoslavia is situated in the eastern part of the Savinian Alps, a chain of mountains running roughly through Slovenia in an east-west direction as the utmost south-eastern extension of the Alps in Europe. It belongs to a typical alpine landscape in the transition zone between a plateau of moderate elevation and the high mountains of the Savinian Alps.(Fig.1).

* This research is the result of a study stay in Slovenia under the direction of Prof.dr. ir. D. Mlinsek. Head of the Forestry Department of the biotechnical Department of Ljubljana. Therefore the author finds himself very indebted to D. Mlinsek and wishes to thank him herewith.

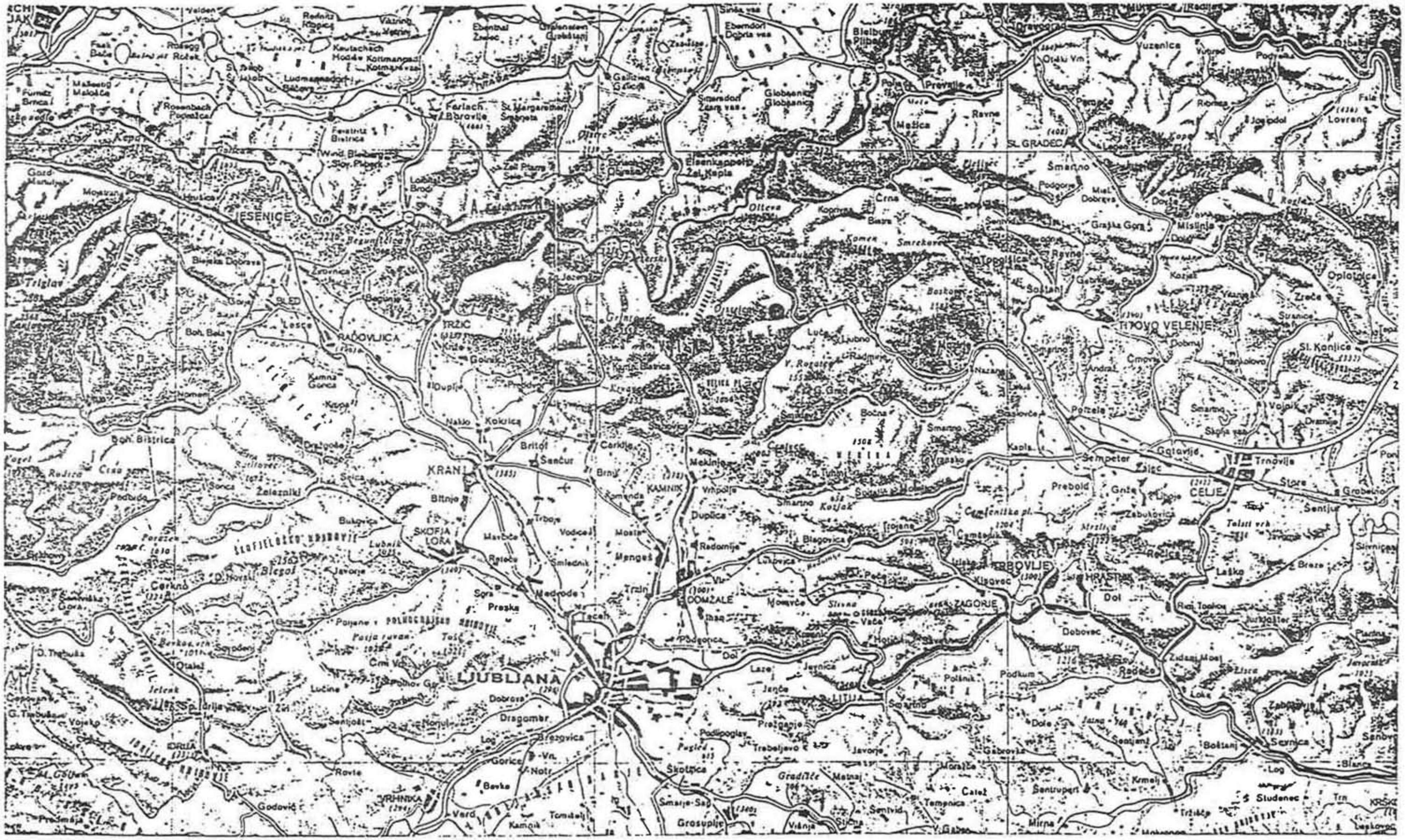


Fig. 1 Geographic situation of the forest reserve Poljšak (scale : 1/500.000).

The entire reserve is exposed east by north-east. It is situated on a mountain-side, containing a number of separate hydrobiological basins, dry dells and steep slopes.
The elevation varies between 950 and 1800 m above sea-level over a horizontal distance of barely 2100 m, corresponding to a declivity of 22° or 44 %.
The forest reserve Poljsak covers 342 ha. Its subsoil belongs to a Middle- and Late-Trias limestone formation over a darker shell-limestone and dolomite. It is covered by palish Dachstein-limestone as is the case on most mountain-tops of the Savinian Alps. As a result of the presence of this particular geological stratum, the water acquires an extraordinary eroding and transformative capacity (karst-phenomena), all the more because the eastern part of the Savinian Alps, Poljsak included, belongs to the alpine-arctic climatic type.

1.2. Tree species

The stands in the forest reserve Poljsak are dominated by beech (*Fagus silvatica L.*), norway spruce (*Picea abies (L.) Karst.*), european larch (*Larix decidua Mill.*) and mountain pine (*Pinus mugo (Ant).) Hoopes*). These principal species are occasionally intermixed with secondary species such as *Salix glabra*, *Juniperus communis ssp. sibirica*, *Sorbus aucuparia*, *Salix grandifolia* and *Sorbus chamaemespilus* which never attain dominant status, are exclusive site-occupants or represent a considerable share in total biomass.

1.3. Historical background

The forest reserve Poljsak has passed through a long history of quite a number of devastating anthropogeneous and zoogeneous influences, put under control or terminated only 6 years before the present study was undertaken. Therefore the actual condition of the forest is not to be equated with a real virgin or absolutely natural situation as could be understood by misinterpretation of the term " forest reserve ". The legal statute of " forest reserve ", implying complete and effective prohibition of cutting practices and other kinds of forest use, was but recently acquired (1978).
Before 1978 the forest was submitted to regular exploitation over, at least, 3 decades with extremely heavy cuttings over a period of 4 years from 1948 to 1951. Between 1948 and 1978 about 8500 m^3 of timber (24.8 $m^3.ha^{-1}$ or an average of 0.8 $m^3.ha^{-1}$ y^{-1}) was cut in the actual area of the forest reserve, the greater part or 7000 m^3 during the first 4 years (1948-51) of the exploitation period, corresponding to an average of about 20.5 $m^3.ha^{-1}$ or 5.1 $m^3. ha^{-1}. y^{-1}$.
Exploitation was mainly concentrated on norway spruce (95 %) and, partially, on larch.

Some artificial stands, planted in 1954 and 1957, lay within the perimeter of the reserve. They illustrate, by their sheer presence, the impact of human intervention.

A long tradition of cattle breeding and use of the forest for grazing has put its stamp on the area. For quite a long time the forest was subservient to the interests of the herdsmen, who, frequently and repeatedly, cut the forest or burned down the original vegetation to promote grass-growth and the extension of their pastures.
Before 1940 at least separate alpine pastures were in use in the immediate neighbourhood of the actual forest reserve. On these pastures 200 cows and 1000 to 1500 sheep were herded each year, together with an unknown, but, probably, rather restricted number of goats and horses. As of 1945 grazing in the forest was abolished officially, partly because cattle-breeding had lost importance in the region. As a consequence, 4 out of 8 alpine pastures near the reserve were abandoned definitively.

The influence of grazing in Poljsak nevertheless persists, especially because cattle and sheep, belonging to nearby Ravne-pasture, regularly transgress the boundaries of the forest reserve.

1.4. General aspect of the forest vegetation

Next to the impact of traditional forest use, the vegetation in the area is subject to the action of prevailing climatic conditions through their direct influence on physiological processes and their indirect repercussion on growth by activating soil development.
Climatic conditions tend to become more extreme with increasing elevation in mountainous regions. Hence, growth-conditions show a systematic variation linked to altitude. The vertical vegetation-gradient is, consequently, related to an altitudinal succession of vegetation-belts, to identify by the specific aspects of their composition, structuration, appearance and developmental dynamics. This kind of spatial distribution of forest vegetation by an altitudinal succession of forest types is considered as a zonation, a concept defined rather simply, but tersely by Packham and Harding (1982): Zonation is the segregation of various species and communities in space.
The analysis of zonation, whether considered as a hypothesis or accepted as a reality following visual observation in a global way, must go out from cartographic and numeric data.
Information can be obtained by two methods, used separately or linked to each other :

- Total reconnoitring of the area to map the distribution of species,in the present case of tree species within the reserve.

- Laying-out of well defined transects, useful to study the terrain-profile, the distribution of species and the spatial variations in vegetation structuration.

2. THE TREE SPECIES AT POLJSAK

2.1. Method of analysis

In the course of the systematic survey of the whole territory of the forest reserve Poljsak, particular attention was paid to the presence and the relative importance ad hoc of beech, norway spruce, european larch and mountain pine, considered as the main species and principal elements in forest structuration. This resulted in the elaboration of a map, depicting the distribution of the cited species, based on the acceptance of a number of criteria or definitions (Fig. 1) :

Tree line

The line connecting the points where solitary or individualized trees, reaching a maximal height of 5 m, are growing (Leibundgut, 1938) This definition is arbitrary, although acceptable.

Timber line

The definition by Rübner (1960) is regularly used in Europe :

> " Boundary where the forest stand ceases to exist as a closed social unit with a sufficient degree of density a typical forest climate, covering a minimal area ".

This definition is extremely vague. The absence of objective norms, compels to a rather subjective interpretation of a given situation and is therefore of little practical use in the field.
Therefore preference was given to the concept of Mutch, defining the timberline as " ... the line connecting all places where trees or isolated groups of trees are at most 30 m far from each other."
The definition is also not perfect. The term " group " is not defined unequivocally. However, the definition has proven to be useful for practical purposes.

Area boundary

For beech and norway spruce, the sole real dominant species, the points were mapped, where a species loses its dominant position is the stand (over 50 % of the number of dominant trees) in favour of another tree species.
By connecting these points by a line, the area, where a given species is dominant, can easily be delimited.

Vegetation zone (or belt)

For each tree species the points were noticed, where the last specimen of the species is found, irrespective of its dimension or social position.
The lines, connecting these points, serve to define the circumscription of each of the five recognized vegetation belts. (Fig. 2.).

It is evident that mapping, resulting from direct field observations, based on the above mentioned definitions, is imperfect. In some cases, estimations had to be made, because the use of instruments was out of question. In other instances, desirable observation points were inaccessible, because of steep clefts or deep precipices.

2.2. Observations

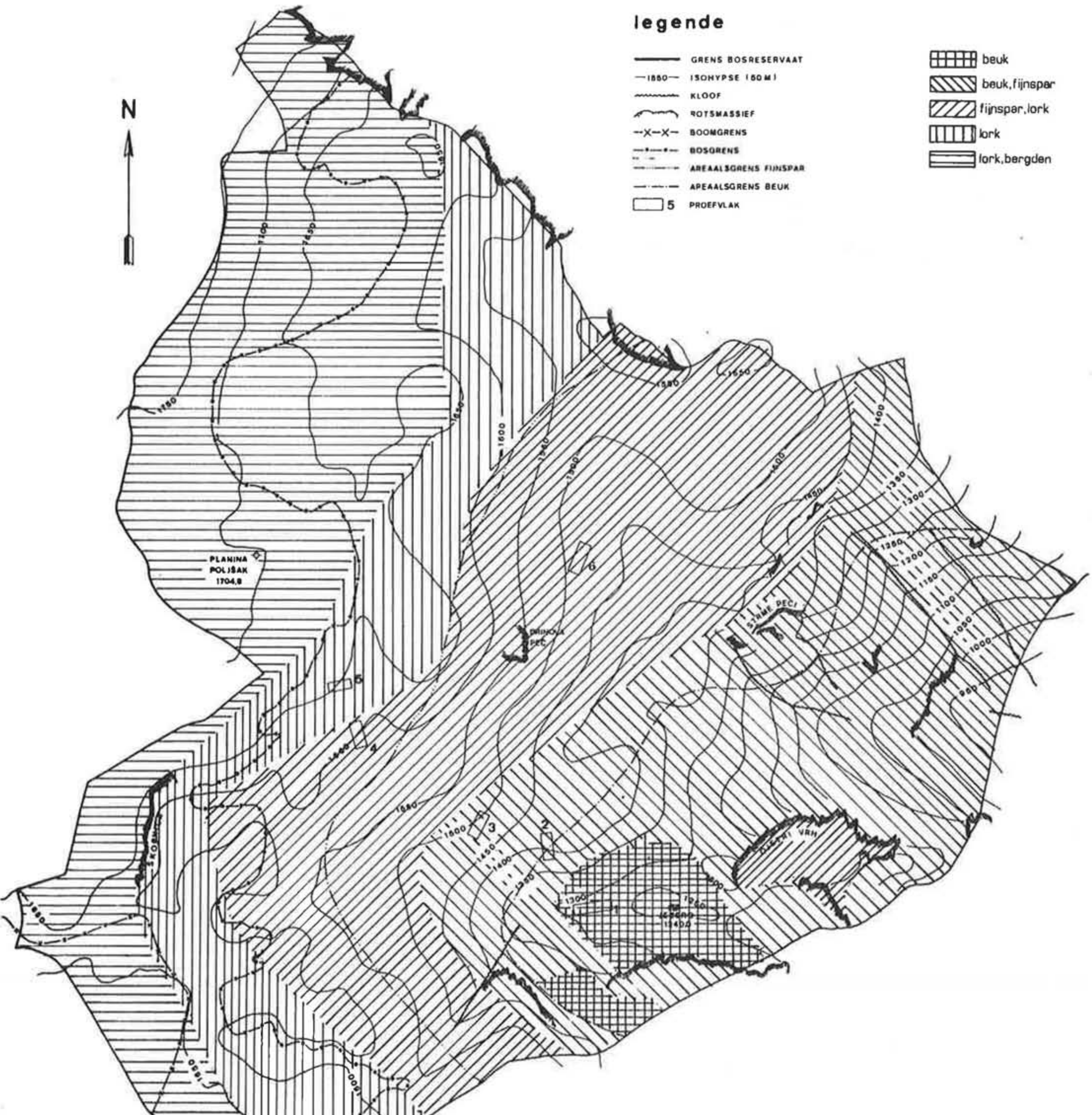
The observations on different aspects of the spatial distribution of the main tree species, allow to work out a zonation-model. It depicts the actual situation at Poljsak and can be used as a base for speculation on possible developments and evolutions.
The zonation model uses as its criteria : the cripple-line, the cripple-zone, the treeline, the combatzone and the timberline.

2.2.1. The cripple borderline

The line, connecting the points were the last traces of isolated trees and crippleforms of woody growth, reaching an ultimate height of less than 5 m, are found, runs beyond the actual boundaries of the forest reserve.

2.2.3. The cripple zone

The cripple-zone, situated between treeline and crippleline, can only be found in the south-western part of the reserve.
In this zone isolated larches with a distorted habitus grow strongly scattered. They remain smaller than 5 m and occur in a fairly dense and scrubby stratum of low-growing, multistemmed mountain pines.
This scrub-vegetation is frequently interrupted by bare place where the calcareous substratum surfaces.


legende
GRENS BOSRESERVAAT
1880
ISOHYPSE (50 M)
KLOOF
ROTSMASSIEF
BOOMGRENS
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The cripplezone depicts a fairly static situation, where the actual positions can be maintained over a long period of time on account of extreme ecological conditions, extremely slow growth and the low frequency of seed-years.
A typical outgrowth strategy is followed by the woody vegetation.
There is no indication of the sequency of species to be expected after eventual total destruction of the actual vegetation by external causes. It is quite possible that both species, now present, will reappear simultaneously.

2.2.4. The tree-borderline

The tree-borderline is situated at an altitude of 1610 to 1700 m above sea level.
It has a total length of 975 m within the forest reserve.
Larch, over a scrubby undergrowth of mountain pine is the only species with a true tree habitus to be found there. It appears to be the climax-species with mountain pine in a marginal position.

2.2.5. The combat-zone

The combat-zone, situated between tree-line and timber-line, appears as a band, running roughly north-south in the western part of the reserve.
It is supposed to be in a rather dynamic state on account of expected transgressions and regresssions over the borderline of the forest as a closed community. As of yet, there is no indication of the frequency, extension or periodicity of this phenomens.
However, the dynamic nature of this ecotone or transition area is sufficiently illustrated by its heterogeneity as far as species and their patterns of mixture are concerned.

In the northern part the combat-zone is exclusively colonized by larch and mountain pine in a mixture with a strong structural resemblance to the one found all over the cripple-zone. However, larch grows better here, stands less isolated and forms the real tree-vegetation, whereas mountain pine preserves its scrubby habitus. Previous conclusions on the relationship between both species are thus confirmed.
When descending toward and approaching the timberline, two constatations are made :

- The scrubby vegetation shows a higher degree of continuity. Bared places decrease in number and are smaller. The total and individual extension of the incovered or denuded are decreases.
- The larches are gradually united into cells of 3 to 5 touching trees, developing into ever larger groups with decreasing altitude. Simultaneously the distances between cells and groups diminish progressively.

More to the South, mountain pine becomes less important and the lower parts of the combat-zone near the timberline are nearly completely occupied by a homogeneous larch vegetation. Larch even assures the transition between tree-borderline and timber-borderline at all places where those two ecological borderlines are close to each other and where the combat-zone is consequently rather narrow.

In other parts of the southern zone however, the area of dispersion of norway spruce is intersected by the timber-borderline. In this case spruces penetrate into the combat-zone, giving rise to localized spruce-larch mixtures and a rather whimsical course of the transition area. Globally the combat-zone at Poljsak is to be characterized by its considerable breadth and the importance of the altitudinal span :

- The altitudinal span of the transition zone varies vertically between 20 to 170 m, creating a rather important variation in ecological conditions.
- Horizontally, the broadth of the combat-zone, defined as the horizontal distance between tree-line and timber-line, measured in a east-west direction and perpendicular on the longitudinal axis of this band-shaped transition-area, varies between 70 and 915 m.

There are puzzling facts, indicative for a situation in full evolution toward a spatial equilibrium, not yet attained as the influences of the chronic perturbations of the past are still working. It is to be expected that the combat-zone, actively covering 80 ha or 23 % of the total area of the reserve, will gradually become less extensive by progressive elevation of the timber-line and transgression of the closed forest over the present borderline.

2.2.6. The timber-borderline

The timber-borderline is made up by 3 different forest types :

- homogeneous stands of european larch ;
- mixed stands of european larch and norway spruce ;
- mixed stands of european larch and mountain pine.

It is noteworthy that, in each case, the european larch is an important component and a common element in all stands nearing the borderline, where the forest ceases to exist as a closed community.

Equally important is the fact that the timber-borderline follows a whimsical course :

* It connects two points on the border of the reserve at a linear distance of 2350 m from each other, but the real total length of the timber-borderline between those points attains 4650 m. (ratio = 1.98).

* The timber-borderline spans an altitudinal lapse of 180 m, discending to a minimal elevation of 1560 m and reaching a maximal elevation of 1740 m.
  The maximal elevations are attained in the northern sector of the reserve. Here it reaches an altitude, where, in the southern part, the cripple-zone already begins.

The rather low elevation of the timber-borderline, combined with its whimsical course, points to the fact that it can not be considered entirely or exclusively as an altitudinal concept. It does not run parallel to the isohypses, but intersects them quite frequently.
Several explanations can be considered as a comment to this state of affairs :

a. Local mesoclimatological conditions, arising from the synergetic effect of specific orographic factors such as exposition, relief, slope etc. must be taken into account. They bring about strong differentiations from the general climatic conditions to be expected at a given altitude. In this way a " Lokalklima " (Mayer, 1976) is created, either benefical or detrimental to local forest development.
   The difference between the northern and southern sector of the reserve engenders some serious doubt about the eventual preponderant influence of local climatic conditions on the fixation of the borderline where the forest ceases to exist.

b. Unpredictable anomalies in the course of the timber-borderline can also be caused by exceptional edaphic conditions. According to Mayer (1976) these quite natural, irregular oscillations of the borderline are characteristic for regions with a high degree of " relief-energy ". This, to a certain extent, could be the case at Poljsak.

c. It could also be put forward that the timber-borderline has been moved down artificially and that its actual course is the temporal result of past and present human intervention, aiming at a local and purposeful destruction of the original forest vegetation for different reasons.

Making a choice between these three hypothesises boils down to answering the question whether the actual timber-borderline is natural (real) or anthropogeneous (= unreal) in character.

Present surveys and available archives do not offer a direct solution to the problem. No analysis of the different aspects of the forest complex was undertaken in the past and no inventories were made. There is, consequently, poor knowledge about former position and course of the timberline, as well as about its modification and the influence of different factors of change. Even if there really is no doubt about the anthropogeneous nature of the present position of the borderline, it seems impossible to determine unequivocally over which vertical distance or altitudinal span such an artificial regression occurred.
On the other hand, there is sufficient evidence that the actual timber-borderline does not correspond to a natural equilibrium. Its origin and position are not merely nor exclusively due to the action of natural processes, both biotic and abiotic.

According to Mayer (1976), oscillations of the natural timber-borderline are mainly dictated by the local exposition of the terrain. He illustrates this point of view by the statement that the timberline (Waldgrenze) and other ecological boundaries as well move downward if the slope receives less direct solar radiation (North-exposition = Schattenseite)
It is doubtful of this explanation applies to all situations, including the arid and semi-arid sites where loss of moisture could be more important than radiation energy input.

At Poljsak the coupling of terrain orography and radiation circumstances, on one side, and the tracé of the timber-borderline, on the other, seems less obvious, if not completely out of question. Equally unsuitable is the hypothesis that natural fluctuations of the timberline are induced by small-scale edaphic variations as the same geological substratum i.c. calciferous rock, is evident all over the forest reserve

Ellenberg (1963), expresses a further reaching opinion by this statement that, in the absence of any form of direct human influence, the borderlines for isolated tree growth and closed forest formation are to be found at nearly the same altitude : " ... a forest stand of substantial extension, with a specific structure and a typical forest climate can develop at all places where vital tree-growth is still possible. This opinion, accepted by many silviculturists, leads to the logical deduction that, under natural conditions, the combatzone is very narrow, if not completely absent. Inversely, it allows to interpret a broad combat-zone as an indication for intensive human intervention ... or frequent perturbation by natural causes.
In the case of Poljsak, where no evidence of regular natural disturbances exists, the acceptance of Ellenberg's theory implies that the considerable extension of the combat-zone, in vertical as well as in horizontal direction, may be used as an argument to prove the anthropogeneous character of the actual borderline of the closed forest in the reserve.

Otherwise, it is important that available archives indicate that the forest complex at Poljsak, including the actual reserve, was submitted, for quite a long time, to intensive grazing, partly due to the presence of alpine pastures at Ravne and Poljsak in the immediate neighbourhood.
On behalf of cattle-breeding the forest was repeatedly destroyed by fire or overcutting.
This kind of forest destruction mainly executed at higher elevations in the reserve, where less dense tree growth already allowed grazing had, without any doubt, a direct effect on the regression of the timberline.

Further proof for this thesis is given by the presence of a number of grassy plots without trees, in irregular dispersion found just below the actual timberline. They clearly are abrupt and unnatural interruptions of the more or less dense forest vegetation, by which they are surrounded.
Such a phenomen is fairly common in the Alps.
Wraber (1970) furthermore confirms that in the Slovenian high mountains an overall regression of the timberline over a vertical distance of 200 to 400 m has occurred, resulting from generalized exploitation of alpine pastures and systematic deforestation to increase the possibilities for grazing.

Accepting the opinions of Ellenberg (1963) and Wraber (1970) it is logical to conclude that the actual position of the timber-borderline at Poljsak is co-determinated, to a greater extent, by human influences, mostly in the past. This boundary is unreal and lays below the natural, even below the virtual or potential timberline. More analysis and research is needed to trace the exact position of the natural timberline or to decide to what extent the actual borderline can be moved toward higher elevation.

3. THE VEGETATION ZONES

3.1. Altitudinal zonation

In the forest reserve 5 vegetation zones, each characterized by the presence of certain tree species or a typical combination of tree species, are distinguishable.
The position of the limits between these belts can be concisely represented as follows :

	m above sea level	
	Limits	Average altitude
Larch-mountain pine		
	1590 - 1670 m	1630 m
Larch		
	1540 - 1650 m	1595 m
Larch-norway spruce		
	1350 - 1510 m	1430 m
Norway spruce-beech		
	1260 - 1380 m	1300 m
Beech		

The transition from one forest zone to another does not always occur at the same altitude.
The altitudinal amplitude of the boundary between " spruce-beech " and " larch-spruce " is rather important as the difference between the highest and the lowest point of this line amounts to 160 m within a short horizontal distance.
On the relatively steeper slopes spruce penetrates deeper into the homogeneous larch area. A possible explanation for this phenomen could be that the steeper slopes were less suitable for grazing. Hence the forest suffered less and a light-demanding species, such as larch, had to regenerate in sub-optimal conditions, whereas the more tolerant spruce got protection from the larch-cover.
It is otherwise noteworthy that the actual timberline is built up by three different tree species, understandable by its important oscillations and the fact that it was through three different vegetation belts.

3.2. The position of norway spruce

The position of norway spruce and beech, the most important components of the closed forest stands, deserves particular attention. Beech has its area of dispersion between 1200 and 1440 m ; it loses its dominant position in the stand at an average altitude of 1320 m. Norway spruce is present between 1290 and 1660 m, but loses dominance at an average altitude of about 1600 m above sea level.

It is remarkable that, in the northern part of the reserve, the limit of the area of dispersion of spruce nearly coincides with the transition of the spruce-beech mixture to the homogeneous larch stand. It thus becomes evident that spruce disappears completely out of the mixture at the Point where this species loses its dominant position and potential for ascendency. The transition between both vegetation zones occurs abruptly and not as a consequence of a gradual loss of vitality or the potential for competition of spruce.
The interpretation of this phenomen poses some problem. It would, as a matter of fact, be erroneous either to conclude, without further substantial proof, that this abrupt transition points to specific ecological requirements of spruce that are no longer met or that it is indicative for the limit of human influence due to forest destruction to promote grazing. Applying the theory of Ellenberg (1963) the first hypothesis would led to the conclusion that the limit of natural dispersion of spruce is suddenly reached, which runs contrary to all what is known at present about this species. If the second hypothesis is accepted it is quite impossible to explain why spruce does not penetrate into homogeneous, but not very dense larch stands, where it finds a protecting cover and could regenerate since burning, overcutting or grazing are no longer practized. From the evaluation of the area occupied by each of the distinguishable forest types and by each species separately (Tab. 1), it appears that the spruce-larch mixture covers the greatest area (nearly 30 % of the total area of the forest reserve). In this area increasing dominance of spruce and gradual replacement of larch can be expected. Although larch is present on nearly 70 % of the total area of the forest reserve and spruce only on 55 % (Tab. 2), it, nevertheless, must be taken into account that the ecological amplitude of larch is considerably narrower than the actual amplitude of spruce, illustrated by an altitudinal span in the real forest zone of 370 m for spruce against 220 m for larch.

3.3. Conclusion

The occurrence of an altitudinal zonation of the forest vegetation in the reserve Poljsak, globally assessed by visual observations, is unequivocally confirmed by numeric information and analysis of the limits of the dispersion of species and mixtures.
As the reserve is situated on a regularly sloped mountain-side, the isohypses run parallel to each other all over the area. Since altitudinal zonation is to be understood as the progressive change of a particular aspect of the vegetation, i.e. the forest, in function of increasing elevation, altitudinal zonation in the case of Poljsak implies the presence of a certain number of belts, whose boundaries run quasi parallel to each other. This, quite evidently, can be observed without trouble.

Vegetationzone	Surface	
	ha	%
beech	10,86	3,18
beech - spruce	87,42	25,59
larch - spruce	99,68	29,16
larch	54,29	15,89
larch - mountain pine	89,45	26,18
Total	341,70	100

Tab. 1. Surface of the 5 vegetationzones in the forest reserve Poljsak.

Treespecies	Surface		
	ha	%	% w.r.t. 341,70 ha
beech	98,29	15,90	28,76
spruce	187,10	30,26	54,76
larch	243,41	39,37	71,24
mountain pine	89,44	14,47	26,18
Total	618,24	100	

Tab. 2. Surface occupied by the treespecies in the forest reserve Poljsak.

A direct consequence of this state of affairs, is that a causal connection between altitude and stand composition must be accepted. It, however, remains extremely difficult to describe the exact nature of this connection and to determine the real ecological factors at work, as well as the relative importance of altitude linked natural influences and human activities. It further is evident that the basic pattern of zonation at Poljsak has sound ecological foundations. As such no fundamental modifications are to be expected in the near future, although there can be no doubt about the benificial effects of the abolishment of forest-degrading practices.
In this sense the following evolutions may be reckoned with in the absence of further human interference or drastic natural perturbations : gradual displacement of the timber borderline toward an higher elevation ; reduction of the share of larch in total biomass and of the area, where this species persists,essentially because of its progressive disappearance at lower altitudes ; increase of the share of norway spruce in total biomass and of the area, where this species is present, because of its very probable incursion in the area of the homogeneous larch stands at higher altitudes and its increasing dominance, especially over larch, at lower altitudes ; fixation of the beech belt.
In a view of the vulnerability of spruce, the instability of spruce stands and their acidifying effect on the soil, it is not so evident that the projected evolution will be judged as positive by all instances.
It is therefore necessary to keep a close watch on Poljsak and on two ridges, close to the south-eastern border of the forest reserve, one of which, Ojstri vrk, is well studied. Both orographic entities are extremely interesting, because they represent, on a smaller scale, a repetition of the zonation as occurs in the forest reserve.

4. STRUCTURATION

4.1. Method

For further examination of the observed altitudinal distribution of tree species in the forest reserve, a line transect was set out between lake Jezers (12[illegible]0m a.s.l.) and the abandoned alpine pasture of Poljsak (1704 m a.s.l.). The transect spans an altitudinal lapse of nearly 465 m and has a total surface length of 1320 m.
The main objective of this transect was double : to gain more detailed information and to learn to which degree such a transect could be representative and serve as a sample for the global situation. It was especially interesting to know the extent of the duration of the measurable vegetation limits in the transect from the averages obtained for the whole reserve.

On either side of the transect line an imaginary strip of 0.5 m in width was considered. All trees, where crown touched or overlapped the fictive

band were counted and their height assessed per 100 m section of the transect. For each section the numeric representation of each species was expressed as a percentage of the total number of trees in that section.
A technical difficulty arose at the end of the transect near the pasture, where widely spaced larches are growing in a scrubly stratum of mountain pine. A correct counting of the multi-stemmed mountain pine seemed impossible and not advisable. In this sector only larches were counted, their presence expressed in absolute number. ha^{-1} and the mountain pine retained p.m.
The data, thus collected, were used to draw a global forest profile, based on the topographic map for the area. (Fig. 3).

4.2. Observations

In the lower part of the transect only beech is found. Its share in stand composition diminishes quickly with increasing elevation to reach a zero-point at 1465 m. to be considered as the actual utter distribution limit of beech.
The area-border, where the share of beech reaches 50 % of the total number of trees, is situated at approximately 1430 m A.s.l.
The struggle-zone of beech, covering an altitudinal span of not more than 35 m, is extremely narrow. It is indicative for the quick disappearance and loss of competition energy of beech with increasing altitude.

Spruce enters into the picture at an altitude of 1365 m. to become numerically gradually more important with increasing elevation and the most important stand component with a maximal share at 1580 m. From this point onwards its share drops again and quite rapidly from 55 % to 5 % over an altitudinal difference of merely 100 m.
Consequently, the area-border (1625 m. a.s.l.) and the utter distribution limit (1645 m A.s.L.) are very close together. The struggle-zone corresponds, actually to an altitudinal span of no more than 20 m.

Larch appears at about 1405 m and becomes, numerically, more important with increasing altitude. It quickly dominates stand composition on account on its own increasing faculty for competition and the gradual disappearance of spruce. Larch builds homogeneous and fairly well closed stands from 1640 m. upward till 1685 m. From this point stand homogeneity gets lost, due to the increasing extension of bushy mountain pine, already sporadically appearing at 1640 m. a.s.l.

4.3. Conclusions

The main features of the altitudinal distribution of the stand-building species, assessed through analysis of an altitudinal transect, allow to distinguish between 6 different forest types in the forest reserve Poljsak :

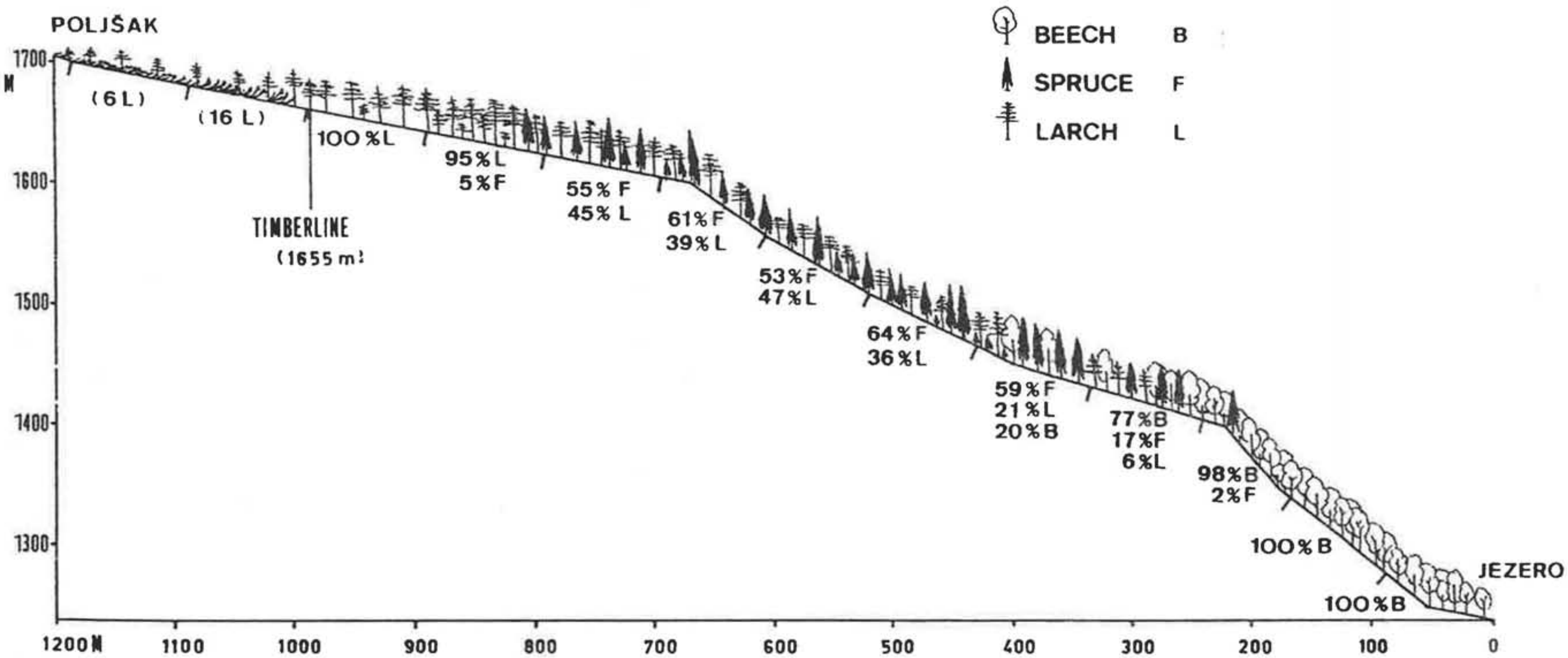


Fig.3 Line transect between the alpine pasture Poljsak (1704,6 m) and the lake Jezero (1240,0 m (scale : 1/5000 -.

Forest type	Utter limits	Area limits
Homogeneous beech* stands	1200 - 1365 m	1200 - 1365 m
Mixed stands of beech and spruce*	1365 - 1405 m	1365 - 1405 m
Mixed stands of beech, larch and spruce*	1405 - 1465 m	1405 - 1465 m
Mixed stands of larch* and spruce	1465 - 1640 m	1465 - 1625 m
Homogeneous larch* stands	1640 - 1685 m	1625 - 1640 m
Mixed stands of larch* and mountain pine	1685 m -	1640 m -

In the immediate reach of the transect line, larch is the most important species, with a share of 46.2% of the total number of stems. Beech (29.9 %) and spruce (23.9 %) have approximately the same importance.

All species cover a rather important altitudinal span, slightly different from the one, deduced from average utter dispersion limits :

Species	Transect		Average	
	Limits	Span	Limits	Span
Beech	1200/1465 m	265 m	1200/1440 m	240 m
Norway spruce	1390/1645 m	255 m	1390/1660 m	270 m
European larch	1405/1685 m	280 m	1430/1650 m	220 m.

These differences are acceptable.
A typical constatation remains also the quick disappearance of beech and spruce at the border of their area of dispersion as indicated by the fairly modest altitudinal span of their struggle-zone.
As a whole, it may be concluded that the transect seems to be rather representative for the general situation at Poljsak. It therefore is acceptable as a suitable method to study the distribution of species and forest types.

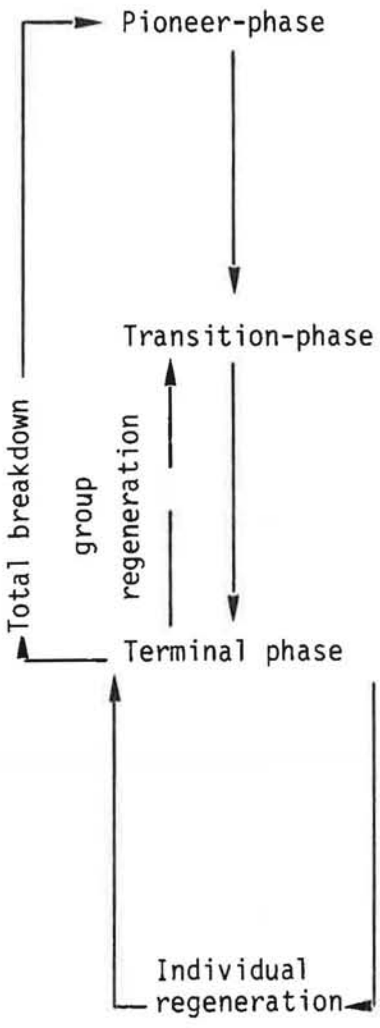
5. SPATIAL ZONATION AND SUCCESSION IN TIME

Although it is the only way to get sound information on change and its mechanisms, the study of the natural or spontaneous forest evolution requires a long period of time.

On the other hand, it is highly precarious to use spatial variation as indication for what may happen in time, because it neglects the importance of time as a working force. It accepts, without proof, the similarity of evolution in time and in space.
A third method, equally speculative, is the confrontation of the actual situation with leading hypothesis about forest evolution in time.
It was thought interesting to try to answer the question whether or not the forest types, as found to-day at Poljsak, correspond with the forest evolution phases considered by Leibundgut (1966).

5.1. The theory of cyclical forest evolution

All forest vegetation is subjected to more or less important change in the course of time. Leibundgut (1966) is convinced that these time-linked structural modifications follow a recurring pattern, provided that human intervention is absent or limited. He accepts a developmental model with three phases, succeeding its each other in a continual sequency of processes, always following the same order ::



Pioneer-phase: Rapid occupation of the denuded site by light-demanding species, producing considerable quantities of light seeds.
They build even-aged, regular and nearly homogeneous stands within a short time.

Transition-phase: Apparition of more tolerant species under the cover of the site-changing pioniers. Gradual development of mixed, uneven-aged stands in which the share in total biomass of the tolerant species is continually increasing.

Terminal phase: Increasing dominance of tolerant species, resulting in nearly homogeneous stands of sciaphile species with a strong tendency toward uniformisation.

Leibundgut (1966) admits that this general model does not always apply. Norma evolution can be modified by frequent anomalies in stand structuration, due to extern perturbation or human intervention.
The continuity of cyclical development with a reserve from terminal phase to pioneer or initial phase is not quite common. It depends upon complete destruction of the forest in its terminal phase over an extensive area (avalanches, stormwinds, snow damage, drought, parasites and pests, human action), allowing light-demanding species with an exploitive strategy to occupy the cleared site and, in doing so, starting a new cycle.
Fixation of any phase is possible either by natural processes, recurring perturbations and local ecological conditions or as a consequence of wilful silvicultural intervention.

Continual regeneration, nearly exclusively of tolerant species, thought to be an essential feature of the terminal phase in the absence of drastic external perturbations, is explained by local stand decay over a small area, liberated by the death of individual dominant trees at different moments. This process creates a pattern of small regeneration groups, perpetuates the dominance of tolerant species and maintains differences in height and age between the trees.
The fixation of the terminal phase with uninterrupted spontaneous regeneration and a sub-maximal biomass is a basic characteristic of silvicultural intervention in the european selection forest as conceived by Ammon (1951), Dannecker (1950) and many others.

The fixation of or a reversal toward the transition-phase with its richer mixing of tolerant and intolerant species, is possible wherever larger areas are cleared by the disappearance, following natural death or organized exploitation, of a cluster of several dominant trees.

An essential feature in the theory of stand evolution, as formulated by Leibundgut, resides in the conviction that in an untouched virgin forest, covering a sufficiently large area, all developmental stages are found and are to be found simultaneously next to each other. This points to the acceptance of the exchangeability of the factors " time " and " space " : variation in space is equated with succession in time.

Going out from this line of thought, the untouched or idealized natural forest is conceived as a mosaic of evolution phases, with three main characteristics :

- The dynamic nature of structural equilibrium as each facet of the mosaic can pass through the described evolution, causing permanent spatial shifting within the mosaic pattern.

- The restricted area, covered by the transition phase if the dominant trees have a long life expectany and resettlement of the liberated areas requires little time, because conditions for stand regeneration are excellent

- The relatively large, covered by uniform phases. This is mainly due to frequent natural perturbations, provoking extensive stand break-down which, consequently, favours quick colonization of the liberated site by heliophile pioniers, followed, in due time, by tolerant species with a conservative strategy for growth, which take over and, by their considerable life expectancy, remain dominant over a long time periode.

5.2. The evolutionary stages at Poljsak

It was thought interesting to confront the situation at Poljsak with the theory of stand evolution in an attempt to make out whether or not the forest types found there are corresponding to development phases, as described by Leibundgut ( ).
This seems sensible as the forest vegetation, indeed, appears as a mosaic pattern, however with restricted variation, in which three types are recognizable, which could be equated, superficially, with three stages of forest evolution :

* Homogeneous stands of the heliophile european larch at the highest elevations, to be considered as a potential pioneer phase.
* Mixed stands of spruce (tolerant species) and larch (light demanding species) at medium altitude, tentatively equated with the transition phase.
* Homogeneous beech stands and mixed stands of beech ans spruce at lower altitude, which could be seen as representative for a theoretical terminal phase.

The basic problem here is to know whether or not each of this type can be considered as a separated entity, following its own lines of development.
Secondary questions are to be answered : Is each type a temporary part of a time-dependent pattern of evolution as sketched by Leibundgut (1966)
Is the present mosaic of distribution of tree species static or dynamic in character ? is the perceived altitudinalzonation accidental or does it respond to a lawful distribution ?

Before answering these questions, attention must be paid to certain facts, able to elucidate the actual situation.

1.

The mixed stands of larch and spruce, tentatively considered as the transition phase, cover about 26.2 % of the total forest area. Such a high share of uneven-aged, mixed stands, does not correspond to a situation where

- a. forest regeneration, although not easy, does not pose any real problems;
- b. the life expectancy of both species is rather high. It does not corrobate the constatation by Leibundgut (1966) that the transition phase of marked inegality and gradual structural breakdown is only observed on a restricted area in the virgin forest. In fact, no traces of structural breakdown are found in the larch-spruce mixtures at Poljsak.

2.

If the mixed and unevenaged stands of spruce and larch, found at an altitude between 1430-1465 and 1595-1640 m, were to be considered as a transition phase, it would be logical to expect increasing dominance of spruce and gradual disappearance of larch, with formation of nearly homogeneous spruce stands as the ultimate consequence.

Such a tendency is not observed at Poljsak. As a matter of fact, spruce loses its ascendency in the mixed stands quite abruptly and nearly always at an altitude of about 1600 m. The area-border of spruce shows, on the other hand, a rather small altitudinal oscillation and runs practically parallel to the isophypses. If the concept of Leibundgut would be applicable in this case, the ensuing consequence would be that all spruce-larch stands, found above 1600 m, would be younger than those occurring beneath this isohypse. This appears extremely incredible, if not absurd.

It is equally strangethat nowhere in the reserve, let alone in the spruce-larch belt, the supposedly ultimate evolution phase of the spruce-larch mixture, i;e. the homogeneous spruce stand, is found.
Referring to the Leibundgut-thesis, this would have to mean that all spruce-larch mixtures under the 1600 m-isohypse, should have to be considered as the second sub-phase of the transition stage, with spruce clearly dominating, but larch still present. It would also imply that over an area of nearly 23 % of the forest reserve all stands would belong to nearly the same age-class, which is highly improbable and runs contrary to actual observation.

3.

There is plain evidence that the relative dominance of spruce in the spruce-larch mixture is related to altitude and is not to be considered as a feature of a time-linked development.

Therefore the spruce-larch stands are not the expression of a time-linked situation, from which, ultimately, homogeneous spruce stands would arise. They are static in nature as the mere consequence of the overlapping of the normal areas of dispersion of two species. The relative dominance of one species or the other is determined by the position of each point of reference within the area of dispersion of each species.

4.

In the lower vegetation zone, where only homogeneous beech stands grow, the forest is in a state of fairly extensive breakdown. At different points completely liberated areas of not less than 2000 m^2 are in evidence. A descended area of this extent is amply sufficient to allow natural resettlement with heliophile species (Kramer, 1933), if such species are available Leibundgut (1966) also states that, when perturbations of this extent occur in the terminal phase, suitable conditions are created to let succession start all over again, beginning with colonization of the site by heliophile pioneers.

In the opened-up spaces of Poljsak, however, only seedlings of spruce and beech are found. There are no seedlings of larch or of other heliophile species. Larch clearly is not able to regenerate at this lower altitude, notwithstanding its essential contribution to stand formation at altitudes of at least 1430 m. This leads to the conclusion that the homogeneous beech stand is not a terminal stage of a larch-spruce-beech sequency. It is only the result of the relative dominance of beech, nearing its ecological optimum, in a zone where the areas of dispersion, of beech and spruce overlap, but with spruce in an outspoken marginal position.

5.

At higher altitudes in the reserve, homogeneous larch stands occur.They are not uniform in structure. The trees belong to a wide range of age-classes. The larch stands do not possess the essential characteristics of the typical pioneer phase, resulting from quick colonization of a liberated site by heliophile species.

If, nevertheless, it would tentatively be tried to consider the homogeneous larch stand as a pioneer-phase, fitting into the scheme of classical stand evolution, this would imply acceptance of

A previous stand history, marked by quick colonization of a bare and uninterrupted band-shaped area of about 54 ha (16 % of the reserve), originating from a single exogeneous perturbation.
There is no evidence of such a perturbation. Even former grazing practice has never been so intensive or well-organized, that it could provoke this kind of forest destruction.

Otherwise, evident differences in age speak out against acute resettlement.

A tendency toward future development, marked by the penetration, after some time, of a more tolerant species such as spruce, able to eliminate larch gradually.
Such a development is highly doubtfull. No trace of spontaneous spruce regeneration nor of any other tolerant species is observed in the larch-belt.

5.3. Conclusions

The secondary species, belonging to the genera Salix, Sorbus and Juniperus at lower altitude, or represented by mountain pine at the highest altitudes never attain dominant status. They never dominate site occupancy. Their share in total biomass is negligible.
They never replace primary species such as beech, norway spruce and european larch. They build a feebly developed understory (hardwoods) have a scrubbe habitus (mountain pine).

Actual assessment of the situation at Poljsak indicates that the present mosaic of distribution of the primary species (beech, spruce, larch) is static in character. It is mainly determined by the ecological situation of the species in function of altitude. No spectacular modifications of the borderlines between the successive, altitudinal vegetation belts must be expected as long as no drastic extrogeneous perturbations occur.

The three basic forest types, observed in the reserve at Poljsak, are not considered as successive stages of an unique, time-linked requency of species as depicted in the forest evolution model by Leibundgut.
The manifestation of each species at a certain point is the expression of the availability and viability ad hoc of the species, its owh life history and the specific ecological conditions, primarily defined by altitude.
This does not imply that evolution in each belt has completely stopped.
It simply means that

- the succession heliophile species - sciaphile species is not to be expected because of the unavailability of a sufficient number of species.

- in certain instances, especially on extreme sites, a climax species, either tolerant or intolerant, can act as a pioneer because of the absence of other species; such a situation implies a rather slow progress of regeneration, creating considerable differences in age.

In the contact zone between successive altitudinal belts, modifications in stand composition and structure are possible, but they are restricted and occur over a very small band, covering altitudinal differences of less than 50 m.

The fact that the vegetation belts at poljsak must be considered as unirs of a spatial succession in vertical direction (altitudinal zonation) and not as units of a time-linked succession must not be understood on a rejection of Leibundguts forest evolution model.
This model remains applicable to all sites where a greater number of species are available and ecological conditions do not impair the manifestation of a different number of species.

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