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CONTEMPORARY RESEARCH ON REGENERATION PATTERNS OF CENTRAL EUROPEAN VIRGIN FORESTS WITH RECOMENDATIONS FOR FUTURE RESEARCH

Andrej BONČINA*, Jurij DIACI**

Abstract

The research of the natural regeneration of virgin forests enables the understanding of forest stand dynamics; the results can be applied to current silvicultural methods. In contemporary researches of virgin forests, two main approaches have been established: the Central European, based on partitioning forest development phases, and the North-American, which emphasises forest gaps. In our article, the general characteristics of gap dynamics and natural regeneration of forests are presented, based on research work of Dinaric fir-beech virgin forests. Natural regeneration is a continuous process, not limited to gaps only, but continuing within all the phases of virgin forest. The gap size is small, the forest cycle is less conspicuous and according to total area, optimal phase prevails. The authors point out the importance of a comprehensive and complex studies of virgin forests, which would enable us to discover the forest structure and its function.

Key words: gap dynamic, natural regeneration, virgin forest (Rajhenav), Dinaric fir-beech forest, Slovenia

NOVEJŠE ŠTUDIJE O OBNOVITVENIH CIKLIH SREDNJE-EVROPSKIH PRAGOZDOV TER PRIPOROČILA ZA PRIHODNJE RAZISKAVE

Izvleček

Z raziskavami naravnega pomlajevanja pragozdnih ostankov spoznavamo razvojne značilnosti gozdnih sestojev, izsledki raziskav pa so pomembni za gojenje gozdov. Pri dosedanjih raziskavah sta se oblikovala dva osnovna pristopa; srednjeevropski temelji na členitvi pragozdnih sestojev na razvojne faze, anglosaksonski pa poudarja pomen sestojnih vrzeli. Avtorja prikazujeta osnovne značilnosti sestojnih vrzeli in naravnega pomlajevanja pragozdnih sestojev nasploh na podlagi raziskave dinarskega jelovo-bukovega pragozda. Naravno pomlajevanje je neprekinjen proces, ki ni omejen le na sestojne vrzeli. Zato je velikost sestojnih vrzeli majhna, ciklični razvoj sestojev manj izrazit, v skupni površini prevladujejo sestoji optimalne razvojne faze. Avtorja zagovarjata in priporočata bolj vsestranske in celovito zasnovane raziskave pragozdov, s katerimi bi lahko spoznavali strukturo in delovanje gozdnih ekosistemov.

Ključne besede: sestojne vrzeli, naravno pomlajevanje, pragozd (Rajhenav), dinarski jelovo-bukovi gozdovi, Slovenija

* dr. gozd. zn., docent, Biotehniška fakulteta oddelek za gozdarstvo in obnovljive gozdne vire, Večna pot 83, 1000 Ljubljana, Slovenija

** dr. gozd. zn., docent, Biotehniška fakulteta oddelek za gozdarstvo in obnovljive gozdne vire, Večna pot 83, 1000 Ljubljana, Slovenija

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1 WHAT IS THE STUDY OF VIRGIN FOREST REGENERATION PATTERNS GOOD FOR?
ZAKAJ RAZISKOVATI OBNOVITVENE CIKLE PRAGOZDOV?

The regeneration in natural forests takes place mainly where canopy gaps occur as a result of broken parts of larger trees (bigger branches, parts of trunk) or where dead standing or lying trees appear - individually or in groups. Small canopy gaps are usually a result of the natural mortality of trees (endogenous regeneration), while larger canopy gaps are often a consequence of external abiotic or biotic environmental factors e.g. wind, fire, snow, extensive bark beetle attacks, etc. (exogenous regeneration). In exogenous regeneration, dead trees usually fall down, contrary to endogenous regeneration where dead trees more often remain standing and therefore are supportive of the regeneration with their shelter (PICKETT / WHITE 1985, BORMANN / LIKENS 1986, NAKASHIZUKA 1983, 1989, STUART / AGEE 1989, URBANSKA 1992, ATTWILL 1994), but there is an important difference between coniferous and deciduous tree species (BONČINA 1997). During the evolution process, each ecosystem is adapted to a specific regeneration pattern, which effects a short-term or long-term stabilisation of species composition. The regeneration pattern, influenced partly by endogenous and partly by exogenous regeneration, is a process supporting the stability of ecosystem structures and maintains the high level of its organisation. In analogous ecological conditions, forest ecosystems permanently tend toward achieving similar structures, which naturally can not be understood as static. Through analysis of natural regeneration patterns, which are one of the most important keys to understanding natural forest structures, we are able to understand the dynamics of the forest which is perceived as a process.

1.1 REGENERATION PATTERNS AND SILVICULTURE
OBNOVITVENI CIKLI PRAGOZDOV IN GOJENJE GOZDOV

A real advance in close-to-nature silviculture could be achieved by imitating natural structures and natural regeneration patterns, which are adapted to local site conditions and symbolise a verified algorithm for recycling developed natural forest structures in past millennia, although this is possible only for relatively preserved commercial forests (for example, in Slovenia, the Dinaric region). Improving changed forests (monocultures) toward more naturally conditioned ones is a much more difficult task, but also in this situation we are interested in seeing how nature cures human-made forests: through destruction, efficient use of remnants, creation of new members, etc. Such and similar information could be perceived from total forest reserves arranged in degraded forest sites and stands.

2 THEORETICAL APPROACH FOR ANALYSING VIRGIN FORESTS
TEORETSKI PRISTOP K ANALIZI PRAGOZDOV

2.1 CENTRAL EUROPEAN APPROACH TO STUDYING VIRGIN FOREST
SREDNJEEVROPSKI PRISTOP K PROUČEVANJU PRAGOZDOV

Dr. Hans Leibundgut, professor of silviculture from Zuerich, was the first to realise the importance of information from virgin forests for a scientific approach to close-to-nature silviculture and its improvement, specially in the changing landscape of Europe. After World War II, he visited many East and South-East European states and forests as an FAO expert. With that opportunity, he also experienced many of the European primary forests (in former Yugoslavia, Czechoslovakia ...) and started a theoretical basis for future research. The main characteristics of his approach - guidelines were first published in 1959 (LEIBUNDGUT 1959) - are the development phases (Ger.:*Entwicklungsphasen*): optimal phase, terminal phase (early, late), decline phase, juvenile phase, selection-forest phase and phase of uniform pole and timber phase forest. This approach was adopted and further developed by numerous researches in Mid-Europe as for example in Austria (MAYER et al. 1989), Slovenia (MLINŠEK et al. 1980), Croatia (ŠAFAR 1953), Bosnia and Herzegovina (PINTARIĆ 1978), Czech Republic (PRUŠA 1985), Poland and in Slovakia (KORPEL 1995). The majority of forest reserve researches in Mid-Europe followed the Leibundgut model, based particularly on the study of stand structure, and the study of development phases. There was also a substantial research effort made with particular emphasis on natural regeneration (for example: MLINŠEK 1967, 1989; HILLGARTER 1971, LEIBUNDGUT 1987, PRUŠA 1985, KORPEL 1988, 1992, 1995, DIACI 1996) and vegetation dynamics (MAYER 1960, 1963, PUNCER 1978, FUKAREK 1970, TRINAJSTIĆ 1970, 1995, BONČINA 1997). Positive aspects of the Central European approach are:

1. Tradition of virgin forest protection and research.
2. The recognition that both - basic and applied research of virgin forest are crucial for improving the management of commercial forest and all renewable resources.
3. An equal research emphasis is given to all the development phases in virgin forest.

The most common negative points of the Central European virgin forest research in recent years have been:

1. The ecophysiological approach to studying virgin forests is not emphasised enough.
2. The research is not sufficiently interdisciplinarily oriented. The zoo-components, or soil component research are presented rather infrequently.
3. A lack of co-ordination in large scale approach. Large-scale, trans-boundary research is stymied by borders and a multiple - small scale ownership pattern, when compared to North America (ecosystem management).
4. European virgin forest researchers were often foresters and therefore strongly influenced by models applied in commercial forests.

2.2 NORTH-AMERICAN APPROACH TO STUDYING FOREST DYNAMICS
SEVERNO-AMERIŠKI PRISTOP K PROUČEVANJU PRAGOZDOV

In comparison with the virgin forest research methodology developed in Central-Europe, the North-American approach was oriented more towards regeneration ecology of virgin forests. The central points are the disturbance patterns of the virgin forest as the main driving forces affecting the dynamics of forest structure and not the forest structures by themselves. The researchers there are mostly ecologists and biologists and therefore not influenced by models applied in commercial forests. For that reason the virgin forest structures were generally considered dichotomous: as canopy gaps and other structures - non-gaps (WHITMORE 1989). Negative aspects:

1. Recently this perspective has attained some criticism, especially due to the loose definition of the canopy gaps. Herewith an effort was made to also emphasise other parts of virgin forest stands through the research methodology (LIEBERMAN et al. 1989). The main reasons are the following: i) the structure of optimal phase strongly affects the regeneration process in the following phase, ii) in virgin forests the "optimal phase" predominates, especially in forest ecosystems driven by an endogenous regeneration.
2. The research is characterised by weakly applied practices. For example within stand management practices (New forestry) are still in incipient phases of development (KAUFMANN et al. 1994).

Positive aspects:

1. Recognising the importance of studying the forest as a process (disturbance patterns).
2. Large-scale interdisciplinary structured virgin forest research.
3. Combined field and laboratory research.

Both approaches have led to a new perception of virgin forests and probably they could supplement each other in the future. On the other hand, they also clearly demonstrate the influence of different culture milieus, where they were formed and perhaps also some signs of magical conservatism (LORENZ 1983).

3 EXAMPLES OF CONTEMPORARY VIRGIN FOREST RESEARCH IN CENTRAL EUROPE
PRIMERI NOVEJŠIH PRAGOZDNIH RAZISKAV V SREDNJI EVROPI

The individual research results can be compared for ecologically similar conditions. In Central-Europe, especially in Slovenia, influences of the Mediterranean, the Alps, the Panonia flatlands and the Dinaric mountains are present; different substrates and diverse orography make the diversity of forest vegetation even more intense. In this areas we face:

- basically different natural conditions (climate, parent material etc.),
- dissimilar forest development dynamics caused by different regimes of natural and human disturbances,
- different fragmentation and naturalness of landscape matrices, where the reserves are located.

The most important consequences of these differences are:

- the need of an adapted research methodology for individual forest sites (for this purpose also forest regions and different vegetation belts could be used as a rough estimate),
- the need of a specific interpretation of the research results and their implementation to the practice of close-to-natural forestry according to natural conditions,
- the need of a Pan-European collaboration on comparative virgin forest research, since the remnants of natural forest are rare and different forest regions are also connecting landscapes inside different political borders.

In this paper some significant results of virgin forest studies in two different vegetation belts and phytogeographical regions of Central-Europe are briefly presented to demonstrate the differences already mentioned above.

The Dinaric region represents natural landscape that has changed less dramatically in past centuries. For this reason, the majority of virgin forests in Slovenia are located in this area where substantial research effort was also carried out.

The subalpine forests in the Alpine region are an example of the agriculturally dominated landscapes of Central-Europe. Only a few remnants of natural forest are still present due to deforestation and pasturing in past centuries.

3.1 STAND DYNAMICS IN DINARIC FIR-BEECH VIRGIN FOREST IN SLOVENIA

SESTOJNA DINAMIKA DINARSKEGA JELOVO-BUKOVEGA PRAGOZDA V SLOVENIJI

The structures of two virgin forests in Slovenia were thoroughly analysed and compared to the structure of a managed forest (BONČINA 1997, 1998): horizontal structure, stand structure of different development phases, plant species and bird species diversity, natural regeneration, dead wood biosubstance, etc. were taken into account. Due to the specific stand-structure of these forests it is not appropriate to show detailed results, therefore only the main conclusions and dilemmas of the virgin forest "Rajhenav" research are presented. The Rajhenav virgin forest is situated in the Kočevje region in southern Slovenia, where forest management began only a hundred years ago. From the beginning, some smaller areas of forest were protected as virgin forest (HUFNAGL 1893). Their area is too small to be considered as a proper virgin forest. Perhaps a more suitable expression to use is remnant of a virgin forests. Carbonate substrate (limestone, dolomite), interferential climate, abundance of participation, different brown soil types of rendzinas, a high forest coverage and well preserved forest ecosystems are typical of this region in Slovenia. Rajhenav virgin forest (51 ha) lies in the mountain vegetation belt with prevailing Dinaric fir-beech forests (*Omphalodo-Fagetum* (TREG.57) MAR. et al.93; syn.: *Abieti-Fagetum dinaricum* (TREG.57) emend. PUNC.79). Fir and beech dominate, other species are in the strict minority. Several analyses were made in this research, and there are also some data available from a century ago. Therefore, the stand dynamics can be described with great certainty.

3.1.1 Horizontal forest structure
Horizontalna struktura gozda

The horizontal forest structure is defined as a mosaic of different forest stands. Some authors prefer "forest texture" (HILLGARTER 1971, OTTO 1994, KORPEL 1995) or "forest mosaic" (AUBREVILLE 1938) or "patch pattern" (WHITTAKER 1975, PICKETT / WHITE 1985, BEGON et al. 1990). The basic element of the horizontal structure is a patch with a stand of certain tree-species composition and development phase or even succession stage. The horizontal structure can be analysed according to size, distribution and total area of the patches. In our case the scale was 1:2500.

In the Rajhenav virgin forest gap-patches smaller than 5 ar dominate. The patch size of other development phases is larger. The largest gap measured 6.5 ar. There is only 0.5 gap-patches in the area of 1 hectare. The cumulative part of the gap-patches in the whole area is 1.2%. As a gap-patch, we determined a part of the forest where tree canopy has been suddenly removed (tree mortality, influences of abiotic factors) and there is neither shrub vegetation nor seedlings and saplings present to the extent that we could consider it as a patch of stand initiation phase. On the permanent plots, it was determined that 114 m^3 of trees pro hectare died out in 10 years, which is about the same as the stand increment. It is interesting that trees of all dimensions are dying out, but in different amounts in different phases. In the late optimal and terminal phase, the distribution of dead trees is more or less similar to clumped (cluster) distribution that affects the formation characteristic of gaps.

A comparison to a beech virgin forest "Krokar", lying only few kilometres away, is very interesting. The site conditions there are more extreme, therefore the percentage of gaps is higher (2.2%). Furthermore, the largest gap patch (20 ar) is also situated in Krokar.

We compared the horizontal structure of the Rajhenav virgin forest to a nearby close-to-nature managed forest. The results show that the total share of gap-patches and stand initiation patches as well as their size are higher than in a virgin forest. According to RUNKLE (1985) the gap formation rate in temperate forests is from 0.5 to 2% per year, while in a tropical rain forest from it is 1.3 to 4.4% by TORQUEBIAU 1986 cit. POKER 1993; mortality rates of canopy trees in coniferous forests of the Pacific Northwest range from 0.5 to 1.0 % (FRANKLIN et al. 1984 cit. SPIES & FRANKLIN 1989).

Natural catastrophes, such as fire, wind-break, ice-break, snow-break, etc. are rare in the mountain Dinaric fir-beech forests. Therefore, the gap portion in the analysed virgin forest is relatively small, as well as the size of gaps. This is also proved by the area and size of stand initiation patch analysis. The total of these patches is also minute, reaching only 2.1% again with the prevailing size of patches up to 5 ar. Additionally, no patches of pole stand, which typically follow as a consequence of relatively bigger disturbance, were found in the analysed virgin forest. This is an additional fact to prove that the cyclical development of stands starts with small-sized gaps.

In the chosen scale, it was impossible to inscribe and analyse (extremely) small gaps. They were too small to be analysed as units of a horizontal forest structure. They were taken into consideration with other types of stand patches, as for example the understorey reinitiation phase, for which small canopy gaps are typical.

3.1.2 Cyclical stand development of Dinaric fir-beech forest
Ciklični razvoj sestojev dinarskega jelovo-bukovega gozda

The main mechanism of gap creation is of endogenous character; i.e. fir mortality. This means a constant source of changes in the stand structure and its dynamics. The percentage of fir, its space distribution and vitality determine the gap size. Here are some examples to illustrate this statement:

- if fir dies out in the optimal phase, the left - over trees, especially beech, fill out the space by lateral crown growth. The effect is similar to results of thinning with a lower density of trees and larger tree-crowns;
- if the percentage of fir is high and the fir dies out uniformly in the whole area (permanent disturbance of small intensity), two-layered stands are formed with beech in the lower layer;
- if firs die out one by one in groups or clumped distributed, the selection (uneven-aged) stand structure follows as a consequence;
- if fir dominates and its mortality is high (a disturbance of great intensity), the stand initiation phase and later pole stands of beech are formed.

The area of the analysed virgin forest and of other virgin forests in Mid-Europe is too small for steady state to be reached. The analysed virgin forest is changing as a whole. The growing stock can not be an appropriate stand-dynamic indicator; it has remained unchanged from the first measurement in 1957 to the last in 1996: 783 m^3/ha, 803 m^3/ha, 802 m³/ha, 799 m³/ha in 798 m³/ha. In the same time, tree species composition and especially diameter structure and horizontal structure have substantially changed. In only a 10-year period, the total area of optimal forest phases has reduced by approximately 15%. At the same time, decline and initiation phases have increased to the same extent.

The cyclical stand dynamics can be more or less evident. As a result of analysing different parameters of Rajhenav virgin forest (diameter structure, growing stock, vertical structure, understorey, dead trees, vitality, etc.) the following conclusions about virgin forest stand dynamics (Figure 1), some of them also typical of other virgin forests in the temperate zone, were made (BONČINA 1997):

- a stand development from gap-patches through young stands to timber stands is rare;
- even less probable is a succession development through different succession stages with shrub vegetation and pioneer tree species. However such development is not impossible as the Badin virgin forest in Slovakia proves (KORPEL 1995), only the possibility is extremely small;
- it is highly unusual that only optimal phase virgin forest is present with only individual trees dying out and others taking their place imperceptibly;
- selection stand structure is relatively often present only in the case of permanent and weak disturbance - usually in more extreme natural conditions.

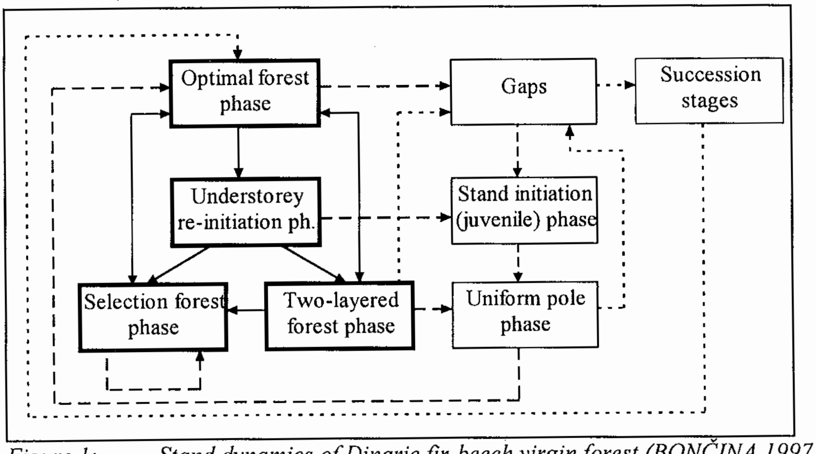

Figure 1: *Stand dynamics of Dinaric fir-beech virgin forest (BONČINA 1997); Lines symbolise the likelihood of different directions of stand development:*
——— most often; - - - less often; ······ very rare

Slika 1: *Razvojna dinamika sestojev dinarskega jelovo-bukovega gozda (BONČINA 1997); Linije ponazarjajo možen razvoj gozdnih sestojev:*
——— najbolj verjeten; - - - manj verjeten; ······ le malo verjeten razvoj

3.1.3 Regeneration in Dinaric fir-beech forest
Pomlajevanje dinarskega jelovo-bukovega gozda

Seedlings and saplings are evident within all development phases and not only within gaps. The analysis shows abundant regeneration at an optimal phase, where growing stock can achieve the highest values (roughly 1000 m^3/ha). At an early optimal phase, the saplings height is small, and by elimination of individual trees from the upper storey, the number of saplings increase, saplings overgrow into higher layers and are already stratified.

Comparison with the managed forest nearby, shows that there is higher density of saplings in the virgin forest of optimal phase than there is in the managed forest of the same phase. We can look for an explanation by assuming that, due to a particular inner environment in a virgin forest, there is less competition between other plant species within a herb layer. The chemical changes within the litter could also affect the regeneration, as there are large quantities of dead biosubstance in a virgin forest, etc.

There are no essential distinctions between juvenile tree species composition in a virgin forest and the close-to-nature managed forest, but far more, there are noticeable distinctions in plant species diversity. Why are there no substantial differences of tree species composition? The reason is simple: the tree composition of Dinaric fir-beech stand is poor; beech and fir are far the most competitive of tree species. There is relatively little shrubbery, therefore the difference between a virgin forest and a managed forest is in composition and in abundance of plant species within a herb layer. In a virgin forest there are 99.5% of fir and beech trees contained in growing stock, the remaining 0.5% is composed of other (e.g. maple, elm, spruce, ...), primarily of light demanding tree species. The proportion of these trees in the managed forest is rather higher (2.0%), what can be contributed to a different inner environment of managed forest. All this raises a question: what is a natural tree composition? It is absolutely natural to find a higher percentage of light demanding tree species in a managed forest, considering the different environment in these forests.

3.2 SUBALPINE FOREST IN THE ALPINE REGION
SUBALPINSKI GOZD V ALPSKI REGIJI

In this chapter, some basic characteristic of alpine forest ecosystems are pointed out, which indicate that this research area requires a specific approach when compared with lower vegetation belts:

- Major exogenous disturbances (as storms, fire, avalanches, etc.) are much more frequent than in lower vegetation belts. Besides major disturbances, there is also the constant pressure of extreme site conditions frequently causing natural selection stand structure (Ger.: *Plenterwald*).
- Because of extreme site conditions, the success of natural regeneration depends on the "coincidence of favourable conditions", especially directly at the timberline (OTT 1989, OTT et al. 1997), where, for example, rare mast years have to coincide with favourable climatic conditions (precipitation, warmth, etc.).
- Not all the microsites could be favourable for regeneration. The more advantageous microsites are occupied by vegetation very fast and some microsites remain bare for ever, resulting in the agglomeration of individuals in clusters (TRANQUILLINI 1979).
- In spite of smaller species diversity, the genetic and structure diversity is high. Therefore research results are very specific and not easily transferable (MLINSEK 1966). For example, consider closed structures of beech subalpine forest with larch and relatively open structures of spruce subalpine forests (DIACI 1995).
- The dead biosubstance is of great importance for alpine forest ecosystems because of nutrient cycling and special habitats for flora and fauna. For example Norway spruce regenerates with a growing elevation more successfully on dead wood component than on forest soil (EICHRODT 1969, HILLGARTER 1971).
- Material cycling is "conservative" due to low temperatures and due to the resistant components the timberline tree species (*Picea abies*, *Pinus mugo*, *Pinus cembra*, *Larix europaea*, etc.) are made from (DIACI 1995).
- The tree species in the subalpine vegetation belt are on the borderline of their natural dispersion. Their growth is, compared with other sites, less intensive. However the individuals can grow monotonously for long periods and achieve high ages (MAYER / OTT 1991).

4 SOME GENERAL FINDINGS
NEKAJ SPLOŠNIH UGOTOVITEV

4.1 REGENERATION IN VIRGIN FOREST IS A PERMANENT PROCESS, BUT THE REPLACEMENT OF OLDER TREES TAKES PLACE VERY RARELY
POMLAJEVANJE V PRAGOZDU JE NEPREKINJENO, NADOMEŠČANJE ODRASLIH DREVES PA LE OBČASNO

The virgin forest research results expose two main principles important for the regeneration ecology of a virgin forest. The first is a permanent adaptation of regeneration strategies to recent ecosystem conditions and the second is abundant continuous arrival and departure of seedlings. Both principles assure the preservation of populations and ecosystems (MLINŠEK 1989, URBANSKA 1992, KLÖTZLI 1993, KORPEL 1995). The adaptation of regeneration strategies suggests that living beings (and ecosystems) do not always follow pre-determined regeneration strategies, but they often adjust to special living conditions (for example, vegetative versus generative regeneration). The abundant and continuous arrival and departure of offspring means that, in virgin forest, everything regenerates permanently, tiny and gigantic, only the regeneration cycles are not alike. The regeneration is always present (individuals are coming and leaving), but the replacement of older trees takes place very rarely. The growth of saplings is permanently in a suppressed position. The result is a strong selection which anticipates the safe development of the coming optimal phase (MLINŠEK 1993).

4.2 IN CENTRAL EUROPEAN VIRGIN FORESTS ENDOGENOUS REGENERATION PREVAILS
V SREDNJEEVROPSKIH PRAGOZDOVIH SO ENDOGENI DEJAVNIKI POGLAVITNI VZROK OBNOVITVENIH CIKLOV

In most Central European virgin forest ecosystems, endogenous regeneration is a prevalent process. Also exogenous regeneration with disturbance processes as wind-break, snow and ice damage, etc. happens often in natural forests, but it rarely occupies large areas or destroys the stands totally. Beech forests in prealpine area of Slovenia are an example of permanent recovery after enduring ice damage.

Large scale disturbances, such as fire, could play an important role at the periphery of the temperate forest as for example on its submediterranean, subpannonic and subalpine borders, where the material cycling can be blocked by drought or low temperatures. On the other hand floods might have been an important natural event and disturbance in the lowland riparian forests.

The horizontal structure of the Central European virgin forests depends mostly on endogenous processes that is in contrary to the managed forest where we actively direct the forest cycle, making it much more distinguished. OTTO (1994) has come to similar conclusions.

4.3 THE "OPTIMAL PHASE" IS DOMINANT
OPTIMALNA RAZVOJNA FAZA PREVLADUJE

Decline phases and juvenile phases are present in temperate virgin forests in small proportions, small spotted and accurately distributed (LEIBUNDGUT 1987, HARTMAN 1987, BONČINA 1997). The different phases of development are mixed up in a mosaic way.

Exceptions could be found among: 1) forest structures driven by large scale disturbances or 2) forest structures in the subalpine vegetation belt with more permanent small scale disturbance and resulting selection structure.

4.4 TREE COMPOSITION IN VIRGIN FORESTS
DREVESNA SESTAVA PRAGOZDOV

It is typical of European virgin forests in the temperate climate zone, to find relatively monotonous tree composition. Depending on growth conditions, beech and/or fir and spruce are prevalent. A bit more diversified are the virgin forests of the flat belt. Looking at the tree composition in a virgin forest we ask ourselves, why less competitive tree species appear at 'normal conditions'. In general, there is little chance for these species to be put forward as the gaps are small. Sporadically, and very seldom, there appear conditions that are favourable for regeneration in an 'average' situation for less competitive tree species. In this way they get forward, that means, they advance to the upper storey, develop good crown, and run to seed. The presence and abundance of these species is indicating the conditions that were prevalent in the past.

4.5 DEAD BIOMASS AS A WARRANTY FOR A PERMANENT PRESENCE OF VIRGIN FORESTS
MRTVA BIOMASA ZAGOTAVLJA OBSTOJ PRAGOZDA

In principle the presence of virgin forest is permanent, even when wind or fire destroy them. Destroyed substances are a warranty for a relatively easy recovery of the optimal forest phase. The decaying biosubstance supports not only the material cycling and a special inner milieu of virgin forest but also directly life and its habitats.

4.6 THE STRUCTURE OF VIRGIN FORESTS IS VARIED
ZGRADBA PRAGOZDOV JE VARIABILNA

In spite of similar stand conditions, some virgin forests have a different horizontal structure. Because of this the results of research work in an individual virgin forest should not be generalised. We can point out certain patterns in the development process. Even if the site conditions in certain virgin forests are similar, the individual stands can differ. The reason for this are differences in the disturbance pattern. The development directions can be very differentiated, some more likely to occur than the others. The future development of an individual forest stand is subject to many factors that we do not know of. Therefore we can only assume what the future development will be and present only statistically, what is characteristic for non-linear dynamic systems. It is much easier to interpret development processes in a virgin forest stand till the present time. Future development always depends on the past. The past is reflected in the future progress of the forest, and many other factors influence it. It is not justifiable to talk about what is natural or even a normal development process of virgin forests. We can only talk about more or less plausible (normal) development characteristics (BONČINA 1997).

5 CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH IN VIRGIN-FORESTS

The starting point in virgin forest research is satisfying, though the influences of forest research in human made forests are still dominant (classic yield and growth, dendrometrical approach, etc.). For example, development phases in the Central European approach originate from human-made forest model (forest of age classes). The virgin forest research took a different shape on different continents and is not coordinated on a world-wide scale nor on a European scale. A co-ordination of such work and development of comparative and interdisciplinary research could mean the beginning of a new era in virgin forest research (MLINŠEK 1993). The structure of the optimal phase and also the structure of all the other development phases affect the regeneration process intensively. For that reason the study of regeneration patterns can not be restrained only to the gap phase. Future forest reserves researches in Mid-Europe should include:

- a higher degree of stand-level ecological features important for nutrient cycling,
- wildlife, their habitats and function,
- more ecophysiological orientation,
- the study of functions of diverse forest structures,
- more emphasis on comparative, interdisciplinary research and large scale disturbances.

Virgin forest research and interpretation of its results should be adopted to different forest sites (as a first estimate also forest regions and vegetation belts could be used), since there are considerable differences in natural conditions, in driving factors of forest dynamics and in the naturalness of natural forest remnants due to the fragmentation of landscape matrix.

With respect to the fact that the remnants of natural forest in Europe are extremely rare and that forest regions are spreading outside political borders, more effort on a Pan-European collaboration on comparative virgin forest research should be made.

When researching virgin forest, we are faced with general problems of researching the complex nature. Very different methods have been applied in order to describe the processes in nature. In doing this we must be aware of the fact that what we do is an anthropomorphic explanation of nature, to which we often (un)justifiably attribute expedience and rationality, even though we deal with coincidental occurrences - in similar conditions the forest structure and its dynamics might be different. Therefore it is important not to exaggerate the analyses of gaps numbers, their area, shape and boundaries, but it may be wiser to redirect our research into studies of development patterns which need a complex treatment. The development processes in the forest ecosystem depend on numerous, even tiny factors. We should, therefore, be satisfied in discovering at least some crucial ones. Nobody is ever going to discover America for the second time, which is, in our case, the structure and function of the forest ecosystem; and this fact makes forest research magic and challenging.

ZAKLJUČKI IN PRIPOROČILA ZA RAZISKAVE PRAGOZDOV V PRIHODNOSTI

Izhodišča za nadaljnje raziskovalno delo v pragozdovih so zadovoljiva, kljub temu da so vplivi gozdarskih raziskav v spremenjenih gozdovih še vedno prevladujoči; prevladujejo klasične dendrometrijske in prirastoslovne analize. Členitev pragozdnih sestojev na razvojne faze izhaja iz proučevanja spremenjenih gozdov in je po svoje dediščina razumevanja gozda kot modela starostnih razredov. Metodologija pragozdnih raziskav se je spontano razvila na različnih celinah, zato se pristopi razlikujejo ter hkrati odražajo vplive različnih kulturnih okolij.

Raziskave pragozdov niso koordinirane v svetovnem in niti ne v evropskem merilu. Uskladitev metodologij in raziskovalnega dela ter razvoj primerjalnih in interdisciplinarnih študij bi zato lahko pomenil začetek nove dobe pragozdnih raziskav (MLINŠEK 1993). Na procese regeneracije pragozdov močno vpliva zgradba sestojev optimalne razvojne faze, kakor tudi sestojna zgradba vseh ostalih razvojnih faz. Zaradi tega ne moremo študija vzorcev regeneracije pragozdov omejiti samo na sestojne vrzeli, kar je značilno za severnoameriški raziskovalni pristop (angl. *gap dynamics*).

V prihodnosti moramo vsebino raziskav pragozdov in gozdnih rezervatov v Srednji Evropi razširiti na proučevanje:

- ekoloških značilnostih sestojev, pomembnih za kroženje hranilnih snovi in pretok energije,
- gozdne favne, habitatov in njihove funkcije v gozdu,
- ekofizioloških značilnosti gozdnih ekosistemov ter
- funkcije različnih gozdnih zgradb.

Hkrati je treba posvetiti več pozornosti primerjalnim in interdisciplinarnim raziskavam ter raziskavam v krajinskem merilu, v katerem lahko analiziramo vplive velikih naravnih motenj.

Metodologija raziskovalnega dela v pragozdovih ter interpretacija rezultatov morata upoštevati rastiščne razmere. Obstajajo namreč velike razlike v naravnih razmerah in poglavitnih dejavnikih, ki vplivajo na razvojno dinamiko pragozdov ter v stopnji ohranjenosti krajine, ki obdaja analizirani gozdni rezervat.

Pragozdni ostanki naravnih gozdov so v evropskem merilu izjemna redkost. Njihov pomen presega politične meje. Zato je potrebno nameniti več poudarka primerjalnim pragozdnim študijam v evropskem merilu.

Ko proučujemo pragozdove, se srečujemo s splošnimi problemi raziskovanja zapletene narave. Za opisovanje naravnih razvojnih procesov uporabljamo zelo različne metode. Pri tem se moramo zavedati, da so naše razlage narave antropomorfne. Naravi namreč pogosto (ne)upravičeno pripisujemo smiselnost, namenskost, racionalnost, etc., kljub temu, da se srečujemo tudi z naključnimi pojavi. Zato sta v podobnih razmerah lahko zgradba in dinamika gozda povsem drugačni. Pri analizi sestojnih vrzelih in naravne regeneracije pragozdnih sestojev je zato pomembno, da ne pretiravamo z analizami števila, površine, oblike in meja sestojnih vrzeli, temveč se preusmerimo v študij razvojnih procesov. Razvojni procesi v gozdnem ekosistemu so odvisni od številnih, tudi neznatnih vplivov. Zaradi tega bi se morali zadovoljiti že, če odkrijemo vsaj nekatere odločilne. Nihče ne bo odkril strukture in delovanja gozdnega ekosistema v popolnosti, odkrivamo lahko le posamezne vzorce v njegovi strukturi in delovanju. Prav to dejstvo pa daje pragozdnim raziskavam čar in izzivalnost.

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