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A development cycle of the forest with fir (*Abies alba* Mill.) and beech (*Fagus sylvatica* L.) in its species composition in the Świętokrzyski National Park

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ABSTRACT: The objectives of this study are to determine the progress of the development cycle of the forest taking into account untypical development periods caused by fir decline and recovery, and to compare the per cent participation of individual phases and periods of forest development in the Święta Katarzyna and Święty Krzyż Forest Ranges of the Świętokrzyski National Park. The development stages, phases, and periods was determined in P_6 fields of the SINUS System of Information on Natural Environment. Tree age distribution, stand structure, volume increment tendency (an increasing or decreasing one), and also the radial increment of fir and beech, and the age of the stand upper story or upper layer were taken as criteria. Fir until about 1960 was characterized by more or less even growth while during 1960–1985 a strong increment collapse occurred, followed by its recovery since 1986. On the other hand, beech during the whole analysed period (1890–1994) did not exhibit any significant decrease in its radial increment. After taking into account the progress of diameter increment of fir and beech the hypothetical series of successive changes of stand phases, mainly caused by decline and then recovery of fir, were developed. Seven new development phases taking place during the periods of decline, recovery and transformation, and not occurring in typical KORPEĽ's (1982) development cycle, are described. New phases were found in 140 P_6 fields out of 206 analysed fields. It was proved on the basis of the fraction equality chi-squared test that there was no reason to reject a null hypothesis according to which the per cent participation of phases during the recovery period in the Święta Katarzyna Forest Range is the same as in the Święty Krzyż Forest Range ($\chi^2 = 2.756$; $df = 3$; p = 0.4308). The absence of significant difference between these two forest ranges indicates, among others, an extensive and strong process of fir decline in the analysed part of the Świętokrzyski National Park (in the Łysogóry Mountain Range). In order to improve the description of the development phases of the forest during the periods of decline, recovery and transformation these studies should be continued, especially on permanent research plots.

Keywords: forest development cycle; periods of decline; recovery and transformation; SINUS System; *Abies alba*; *Fagus sylvatica*; Świętokrzyski National Park

The conception of development stages of forests of primeval character according to which the forest is composed of fragments representing definite development stages and phases is developed in Central Europe, especially in Germany, Czech Republic, Slovakia and Poland (KORPEĽ 1958; LEIBUNDGUT 1959). Each phase is uniform in its structure and corresponds to a certain step in the development cycle of forests of primeval character (e.g. KORPEĽ 1958, 1982, 1991, 1995; LEIBUNDGUT 1959, 1978, 1982; ELLENBERG 1978; MAYER 1984, 1987; JAWORSKI 1997; POZNAŃSKI, JAWORSKI 2000). First, individual development stages and phases are characterized by tree age distribution, stand structure, volume increment tendency, and occupy the area more or less proportional to their duration (KORPEĽ 1982; JAWORSKI 1997). Forest stands with fir (*Abies alba* Mill.) and beech (*Fagus sylvatica* L.) in their species composition, growing in the lower mountainous belt of the Świętokrzyskie Mts., go during their development cycle through the stages and phases similar to those described for the Carpathian Mts. (JAWORSKI et al. 1999).

The fir population in the Świętokrzyski National Park was stable until the early 1960s. However, during 1960–1985 there was a sudden breakdown under the influence of several different factors (SIERPIŃSKI 1977; GRANICZNY, UKLEJA-DOBROWOLSKA 1990; GĄDEK 1993). One of the main causes was a geographical isolation and a small area occupied by fir in the Świętokrzyskie Mts., which may have decided about its limited recombination potential. Under such conditions fir populations are not frequently capable of homeostasis but are subject to ecological disasters, even at sites that meet their requirements (SCHOLZ 1984). Distinct symptoms of fir increment recovery were observed in the 1990s (GRANICZNY, UKLEJA-DOBROWOLSKA 1990; GĄDEK 1993; JAWORSKI et al. 1995, 2000; ZAWADA 2001; PODLASKI 2002). The phenomenon of fir decline followed by its recovery caused the creation of untypical periods, significantly different from stages and phases typical of an undisturbed development cycle.

The objectives of this study are:

A. to determine the progress of forest development cycle taking into account untypical development periods caused by fir decline and recovery;
B. to compare the per cent participation of individual development phases and periods in the Święta Katarzyna and Święty Krzyż Forest Ranges of the Świętokrzyski National Park.

MATERIAL AND METHODS

Forest development stages and phases

A primeval forest is a dynamically equable forest ecosystem developing without any influence of direct or indirect anthropic activities (POZNAŃSKI, JAWORSKI 2000). There are no primeval forests in Central Europe since all ecosystems underwent and still undergo changes caused at least by indirect factors such as industrial emissions or disturbances of hydrological conditions. However, in some areas there are unmanaged forests of primeval character where at the most only single trees were harvested sporadically (POZNAŃSKI, JAWORSKI 2000).

All forests of the lower mountainous belt in the Carpathian Mts. as well as the Świętokrzyskie Mts., mainly composed of fir and beech, go through the growing up, optimal and break-up stages during their development cycle (Figs. 1 and 2). There are different development phases distinguished within these stages (Figs. 1 and 2). The development cycle of each tree generation begins in the regeneration phase and terminates in the decline phase (Figs. 1 and 2). The area occupied by individual

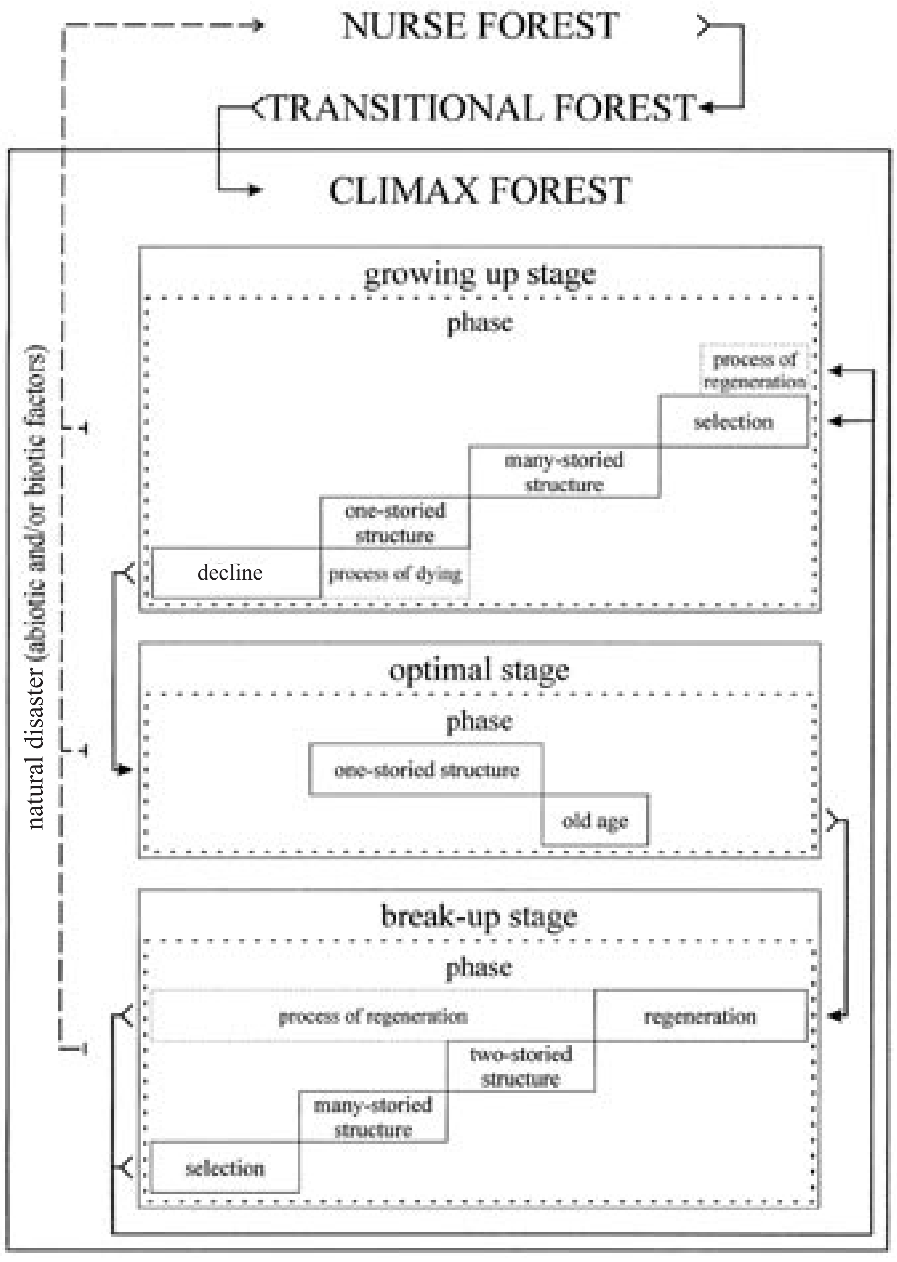

Fig. 1. Development stages and phases of the forest of primeval character, slow stand break-up (KORPEĽ 1982, modified)

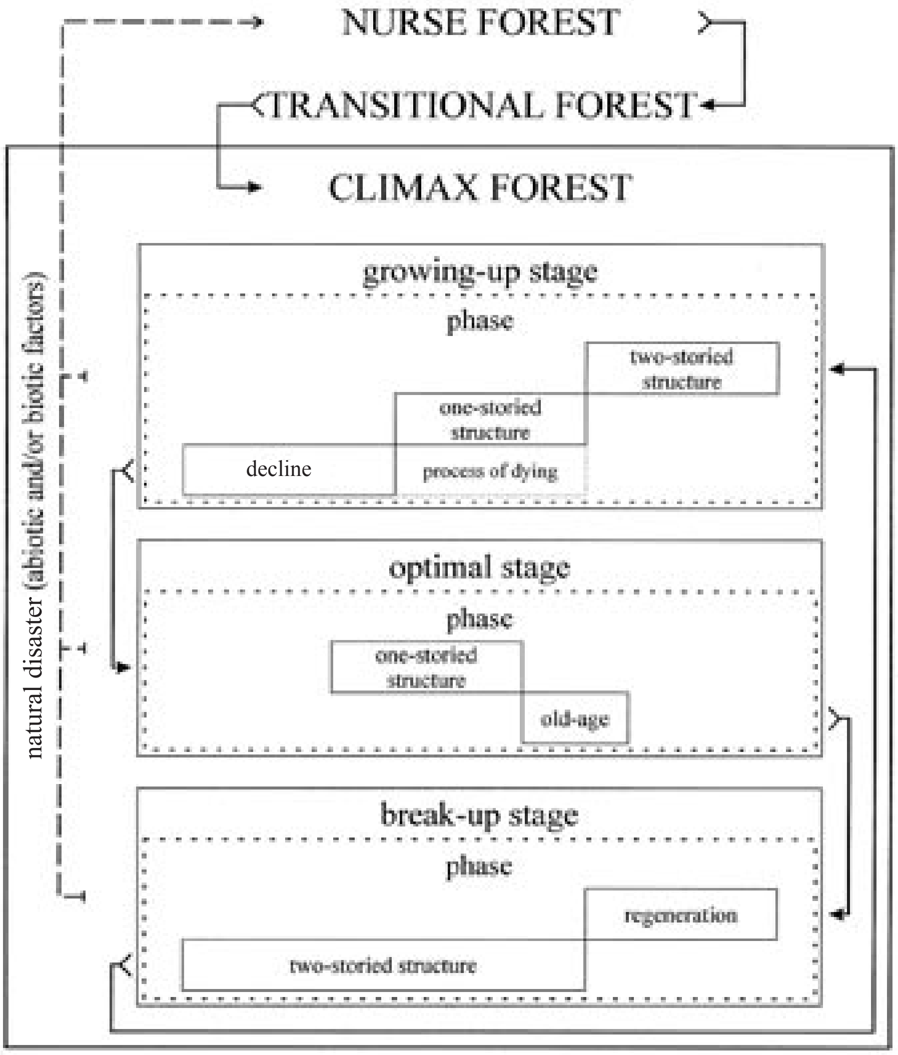

Fig. 2. Development stages and phases of the forest of primeval character, fast stand break-up (KORPEĽ 1982, modified)

stages and phases is from about 0.3 to several hectares (SZWAGRZYK 1988; POZNAŃSKI, JAWORSKI 2000). The total area occupied by individual stages and phases in the entire forest complex is more or less proportional to their duration (KORPEĽ 1982; JAWORSKI 1997). The development stages, depending on the species composition and site conditions, can last from about 40 to about 90 years. In forests of primeval character with beech predominance a full development cycle takes about 230 to 250 years while with fir predominance about 350 to 400 years (LEIBUNDGUT 1978; KORPEĽ 1982; POZNAŃSKI, JAWORSKI 2000).

Description of the SINUS System of Information on Natural Environment

A network of the SINUS System of Information on Natural Environment covers the whole territory of Poland and is composed of blocks – ellipsoidal trapezoids, designated by a symbol P_0, with linear dimensions of about 12,000 × 18,000 m (Fig. 3). The P_0 blocks are divided into P_1 fields of about 2,000 × 2,000 m in size, which in turn are divided into P_2, P_3,..., P_7 fields by division without remainder of fields of the higher order into 4 fields of the lower order (CIOŁKOSZ 1991). A P_6 field, about 0.39 ha in area, is the basic unit of the SINUS System used to determine a development phase of a forest stand, however, P_5 and P_4 fields can also be used. The choice of a particular field of the SINUS System mainly depends on an average area occupied by individual stand development phases in a given forest.

The division into blocks and fields is made in an arc measure, and therefore transformation into a linear measure gives a certain approximation, also depending on latitude. For example, a P_2 field in the Świętokrzyski National Park has the dimensions of 975 × 1,030 m (100.43 ha in area) while a P_6 field is 60.94 × 64.38 m (0.39 ha) in size.

Characteristics of the study area

The investigations were carried out in the Święta Katarzyna and the Święty Krzyż Forest Ranges of the Świętokrzyski National Park. These forest ranges rep-

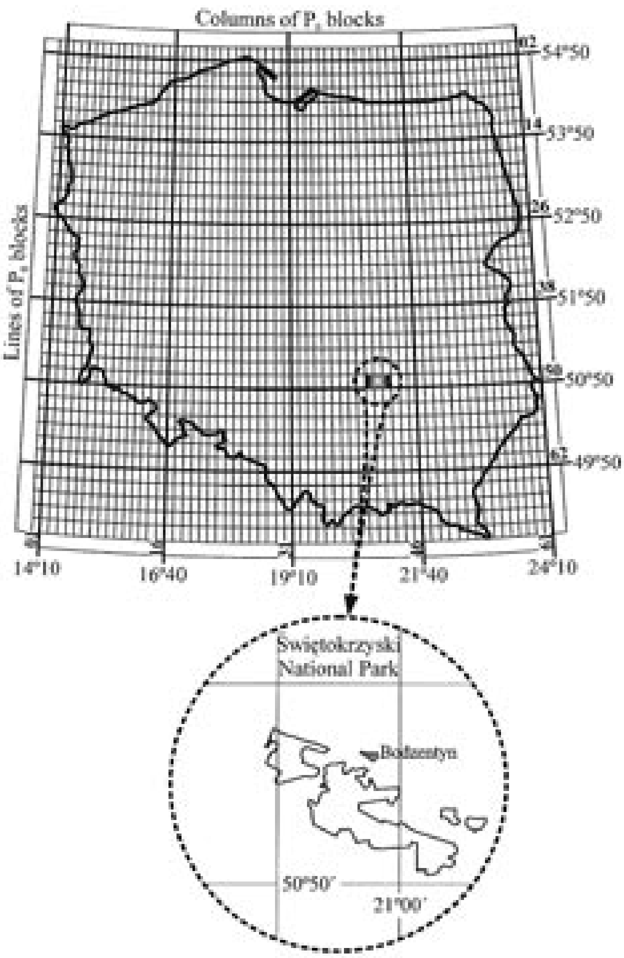

Fig. 3. The network of the SINUS System covering the territory of Poland

resent higher elevations of the Świętokrzyskie Mts., and include some of the oldest strictly protected nature reserves in Poland, created in 1922. The geographic coordinates of the Święta Katarzyna and Święty Krzyż Forest Ranges are: 50°52′–50°55′N, 20°52′–20°57′E, and 50°50′–50°53′N, 21°01′–21°05′E, respectively.

Typical brown and grey brown podzolic soils predominate in the investigated area (KOWALKOWSKI 1991), which led to the development of the following plant associations with fir (*Abies alba* Mill.), beech (*Fagus sylvatica* L.) and pine (*Pinus sylvestris* L.): *Dentario glandulosae-Fagetum*, *Abietetum polonicum*, and *Querco roboris-Pinetum* (the association names are given according to MATUSZKIEWICZ 2002).

The data acquired during a long-term period of observations (1955–1994) at Święty Krzyż meteorological station (geographical coordinates: 50°51′N, 21°03′E; 575 m above sea level) showed that the mean annual temperature was +5.9°C (the mean temperature of January was –5.2°C, and July +15.9°C), mean annual precipitation was 923 mm, and the growing season lasted for about 182 days.

Field work

The investigations were carried out during 1993–1995, and the following were selected in the Święta Katarzyna and Święty Krzyż Forest Ranges:

A. 206 permanent study points in P_2 fields of the SINUS System (103 points in each forest range);
B. 206 P_6 fields of the SINUS System, each 60.94 m × 64.38 m, and 0.39 ha in area (103 fields in each forest range).

The unrestricted simple random sampling with replacement was used. In each P_2 field 10 points were chosen, while in border fields the number of points was smaller, proportionally to the forest area included in a given field. The permanent study points and P_6 fields were selected in a single sampling, i.e. points sampled on the map defined the situation of a permanent point, and at the same time indicated a definite P_6 field. Sampling was made on the forest management map of the Świętokrzyski National Park, scale 1:5,000 (PODLASKI 1999). The permanent study points and corner points of P_6 fields were set out in the forest by offsets.

After setting out the points and fields, fir and beech trees were selected for the radial growth analysis. The radial increment is one of the basic elements serving to determine the phases during untypical development periods of forest stands. In the vicinity of each permanent point one fir tree and one beech tree were selected from the younger as well as from the older generation. Always the trees growing nearest to the point were chosen. The number of selected trees depended on the species composition and age of stands surrounding the permanent study points. In total 207 fir trees of the younger generation from 61 to 120 years of age (at breast height), 49 fir trees of the older generation over 150 years old (up to 300 years), and 199 beech trees of the younger generation from 21 to 80 years old, and 22 beech trees of the older generation above 110 years old (up to 200 years) were selected.

The selected sample trees were permanently marked, and their d.b.h. and height were measured. In the autumn 1994 or spring 1995 two increment cores reaching the pith were taken at b.h. from each tree using Pressler's borer, one on the tree side facing the slope, and the other perpendicularly to the first one. Generally trees of the older generation were damaged by rot to a various extent, and not in all cases was it possible to bore them just to the pith.

The development stages and phases were determined in P_6 fields on the basis of tree age distribution, stand structure, and volume increment tendency (an increasing or decreasing one) according to the method used by KORPEĽ (1982) and JAWORSKI (1997). In descriptions of development periods the progress of the fir and beech radial increment, and the age of the upper story or layer were also taken into consideration, thus distinguishing the younger generation (fir from about 80 to about 150 years old, and beech from about 30 to about 110 years) and the older generation (over about 150 years in the case of fir, and over about 110 years in the case of beech). In order to fully characterize the investigated forest ranges the description of stages, phases, and periods was carried out in the forest of primeval character (existing in some fragments of the strictly protected reserves in Święta Katarzyna and Święty Krzyż), and also in stands not primeval in their character. It should be pointed out that the forests in strictly protected reserves have not been exploited at least since 1950, and in the remaining part of the study area (in partially protected reserves) most of the treatments carried out after 1950 were limited to sanitary cuttings (KRYSZTOFIK 1976).

Data analysis

Measurement, verification and analysis of fir and beech radial increments

In the case of each tree the measurement results obtained from two increment cores were verified by a comparison of the progress of radial increment at b.h. Then the means were computed for each calendar year. The dendroscales obtained for each tree were compared with already existing dendroscales of fir and beech worked out for the territory of the Świętokrzyskie Mts. (FELIKSIK 1987, 1990; JAWORSKI, PAWŁOWSKI 1991; JAWORSKI et al. 1995, 2000).

After measurements and verification of the width of annual rings the mean values and standard deviations of the radial increment of each calendar year were computed for the younger and older generations in both Święta Katarzyna and Święty Krzyż Forest Ranges.

Forest development cycle analysis

The development stages, phases and periods determined in P_6 fields were arranged into hypothetical series of successive changes, mainly caused by decline and recovery of fir. During this study two basic assumptions were made: the one concerning the homogeneity of site conditions and the other a similar development history of stands growing under similar site conditions. It was possible to accept both these assumptions because earlier investigations carried out in this area showed very small site diversification and lack of the effect of long-term, strong and spatially diversified factors lowering the tree vitality (PODLASKI 1999).

Comparison of homogeneity of fractions of the forest development periods

The following null hypothesis was imposed: the fraction of development periods is the same in both Święty Krzyż and Święta Katarzyna Forest Ranges, and also the alternative hypothesis that the fraction of development periods is not the same in both these forest ranges. To verify the null hypothesis the fraction equality chi-squared test (CONOVER 1980) was applied. The homogeneity chi-squared test can be used when expected numbers are equal at least to 5 for each development phase. If this condition is not fulfilled, then the least numerous neighbouring phases should be combined (LAW, KELTON 2000). The essential sense of the whole table after such a combination should be kept in mind, e.g. it would be inadvisable to combine the development phases occurring in different stages or periods.

RESULTS

Radial increment at breast height of the investigated tree species

Fir

The radial increments of fir trees of the older and younger generations in the Święta Katarzyna Forest Range were similar to those observed in the Święty Krzyż Forest Range during the whole analysed time interval (Fig. 4).

The younger fir trees were characterized by the largest width of annual rings during the whole study period (Fig. 4). Mean values of the increment of fir trees of the younger and older generations indicated its strong collapse during the period 1960–1985 (Fig. 4). The maximum collapse occurred more or less during 1980–1985 (Fig. 4). The mean radial increment during the collapse period was below 1 mm in the case of trees of the older generation, and below 1.5 mm in the case of trees of the younger generation (Fig. 4). Since 1986 fir trees have gradually been increasing their increment reaching the value from before 1960 (Fig. 4).

During the period of the strongest increment collapse (1960–1985) the standard deviations of the radial increment reached the lowest values, especially in the case of trees of the older generation (Fig. 4).

Beech

The progress of the radial increment of beech trees of the older and younger generations in the Święta Katarzyna Forest Range was different from that in the Święty Krzyż Forest Range (Fig. 5). The radial increment at b.h. of beech trees of the older and younger generations differed in the analysed period (Fig. 5). During 1890–1994 there was no significant increment decrease (Fig. 5).

The beech trees of the older generation in the Święta Katarzyna Forest Range had more or less constant radial increments during 1920–1994, while in the Święty Krzyż Forest Range a slow, but regular increment decrease occurred especially after 1960 (Fig. 5).

The trees of the younger generation were characterized in both forest ranges by a gradual increase in the mean radial increment until about 1990, and a small decrease after 1990 (Fig. 5). The higher increment reduction after 1990 occurred in the case of beech trees in the Święta Katarzyna Forest Range (Fig. 5).

The radial increment of beech trees of the older generation did not decrease after 1990 (Fig. 5).

The beech trees were characterized by relatively high mean annual increments, in some years above 3 mm in the case of the older, and above 4 mm in the case of the younger generation (Fig. 5).

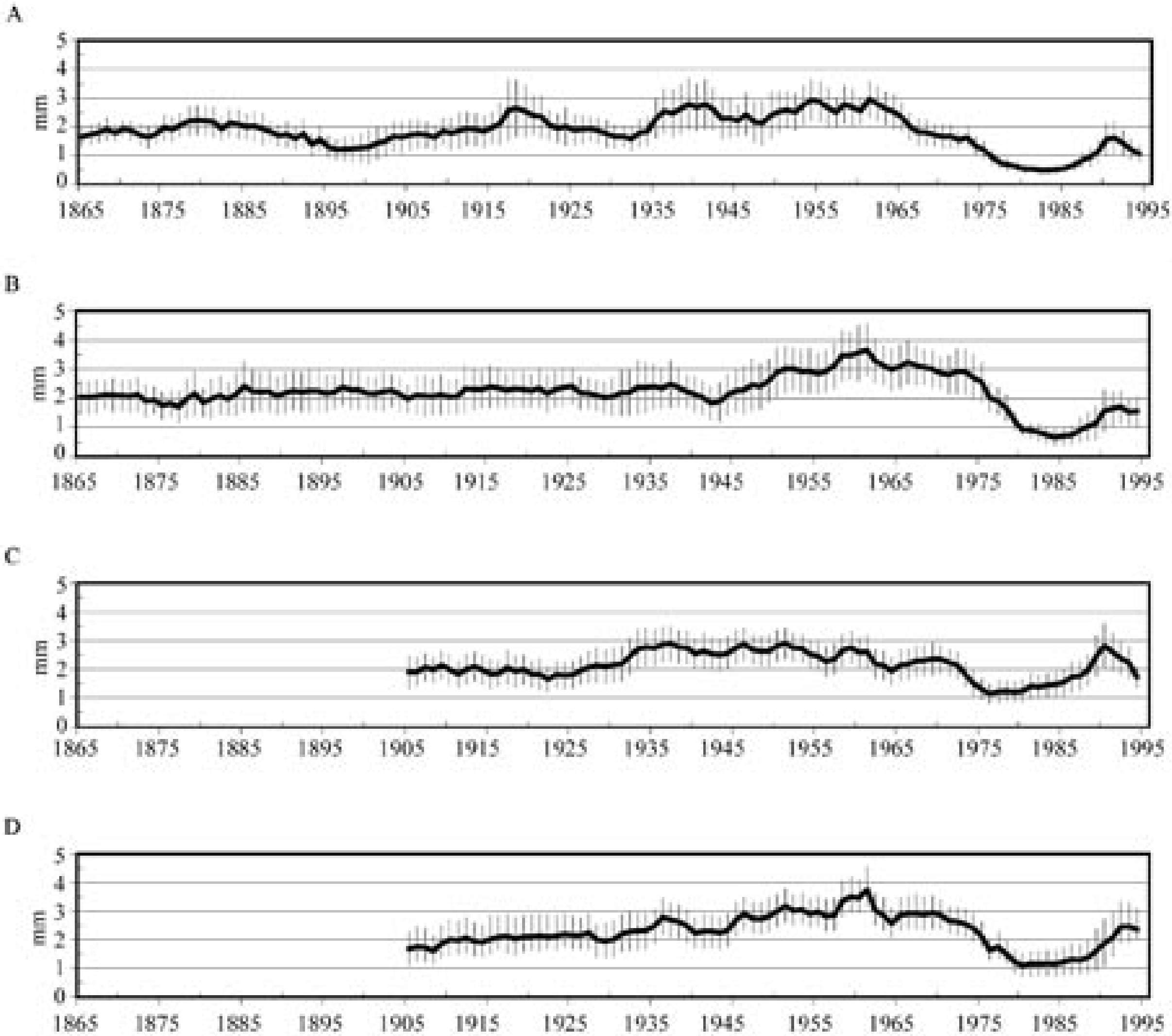

Fig. 4. The mean radial increment (± 0.5 standard deviation) of fir at breast height; A – older generation in the Święta Katarzyna Forest Range; B – older generation in the Święty Krzyż Forest Range; C – younger generation in the Święta Katarzyna Forest Range; D – younger generation in the Święty Krzyż Forest Range

The standard deviations reached similar values during the whole analysed time interval (Fig. 5).

Forest development cycle

Taking into account the progress of the diameter increment of fir and beech, the following untypical stand development periods, different from the development stages proposed by KORPEĽ (1982), can be distinguished:

A. the period of decline – in all development stages and phases there was a break-up of stands caused by very high fir mortality, while the trees which survived were characterized by a strong diameter increment collapse and the stand volume rapidly decreased (in the extreme cases even by 70–90%) (GĄDEK 1993);

B. the period of recovery – in all development stages and phases the process of rapid stand break-up was terminated, trees increased and then recovered their diameter increment, stand volume increased (in the growing up and optimal stages, the one-storied structure phase) or decreased, but to a similar extent like it took place before the period of decline (in the break-up and optimal stages, the old age phase);

C. the period of transformation – it is divided into two stages:

I. stands reach the stages and phases according to KORPEĽ, typical of undistorted development cycles of forests of primeval character;

II. stages and phases according to KORPEĽ (1982), typical of undistorted development cycles of forests of primeval character, begin to occupy the total areas in the whole forest complex more or less proportional to their duration.

The analysis of the radial increment progress of fir showed that in the Świętokrzyski National Park the period of fir tree decline lasted from 1960 to 1985, and it was followed by the period of fir recovery, which in turn, since about 1990, gradually passes into the period of transformation.

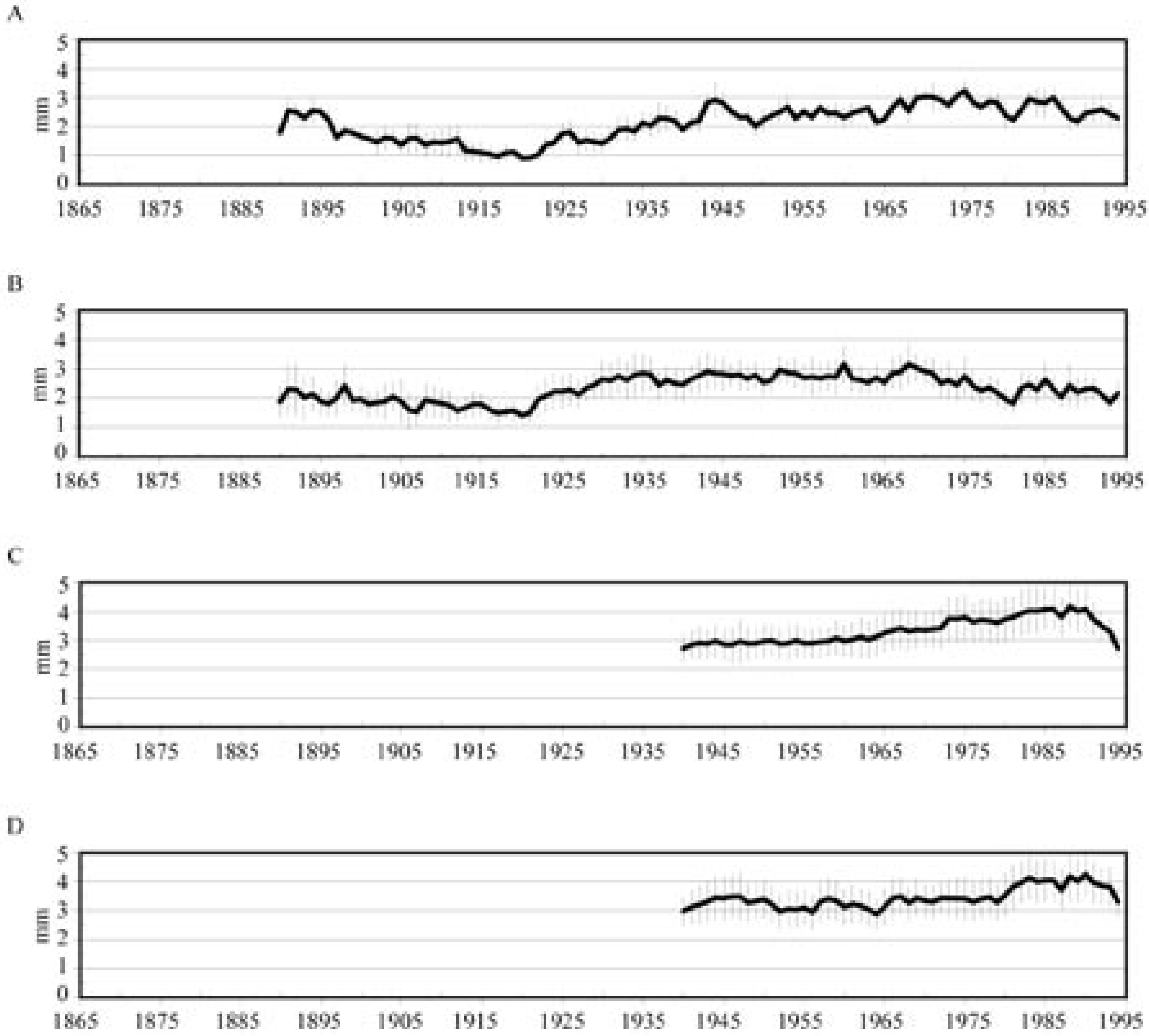

Fig. 5. The mean radial increment (± 0.5 standard deviation) of beech at breast height; A – older generation in the Święta Katarzyna Forest Range; B – older generation in the Święty Krzyż Forest Range; C – younger generation in the Święta Katarzyna Forest Range; D – younger generation in the Święty Krzyż Forest Range

In the P_6 fields investigated in the Święta Katarzyna and Święty Krzyż Forest Ranges there occurred phases not different (66 fields) and different (140 fields) from the phases described by KORPEL' (1982) for the undistorted development cycle. The following development phases were distinguished:

A. typical phases, occurring in an undistorted development cycle:
  1. growing up stage:
     – selection (1 P_6 field);
     – many-storied structure (21 fields);
     – one-storied structure (1 field);
     – decline (7 fields);
  2. break-up stage:
     – two-storied structure (7 P_6 fields);
     – many-storied structure (22 fields);
     – selection (7 fields);
B. untypical phases, characteristic of a distorted development cycle:
  1. recovery period occurring in the growing up stage:
     – many-storied structure [upper layer – younger generation] (12 P_6 fields);
     – one-storied structure [younger generation, and younger generation I and II] (Fig. 6) (27 fields);
     – decline [younger generation I] (Fig. 6) (15 fields);
  2. recovery period occurring in the break-up stage:
     – regeneration [parent stand – younger generation] (10 P_6 fields);
     – two-storied structure [upper story – younger generation] (63 fields);
     – many-storied structure [upper layer – younger generation] (12 fields);
     – selection [upper layer – younger generation] (1 field).

During the decline period mainly fir trees of the older generation die. Fir decline in the growing up stage initiated the following succession series:

A. the selection or many-storied phase in the growing up stage – the decline phase [older generation] during the decline period – the many-storied structure phase [up-

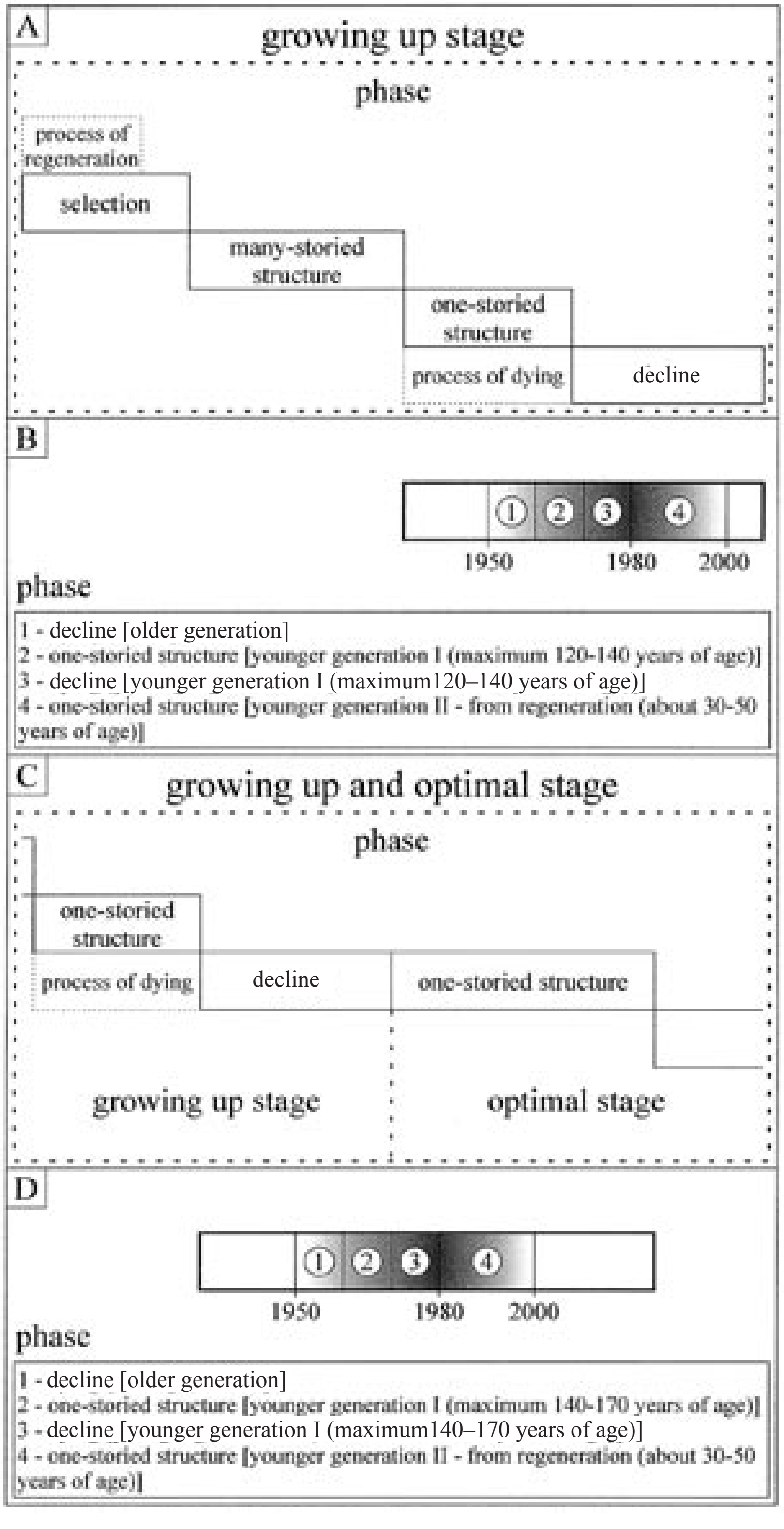

Fig. 6. Hypothetical series of succession changes in the growing up and optimal stages after the periods of decline and recovery; A, C – stages and phases occurring in a typical development cycle according to KORPEĽ (1982); B, D – phases occurring in the decline and recovery periods

per layer – younger generation] during the recovery period;

B. the one-storied structure or decline phase in the growing up stage – the decline phase [older generation] in the decline period – the one-storied structure phase [younger generation] in the recovery period.

Fir decline in the break-up stage initiated the following succession series:

A. the two-storied or many-storied structure phase in the break-up stage – the decline phase [older generation] in the decline period – the two-storied structure phase [upper story – younger generation] in the recovery period;

B. the many-storied structure or selection phase in the break-up stage – the decline phase [older generation] in the decline period – the many-storied structure phase

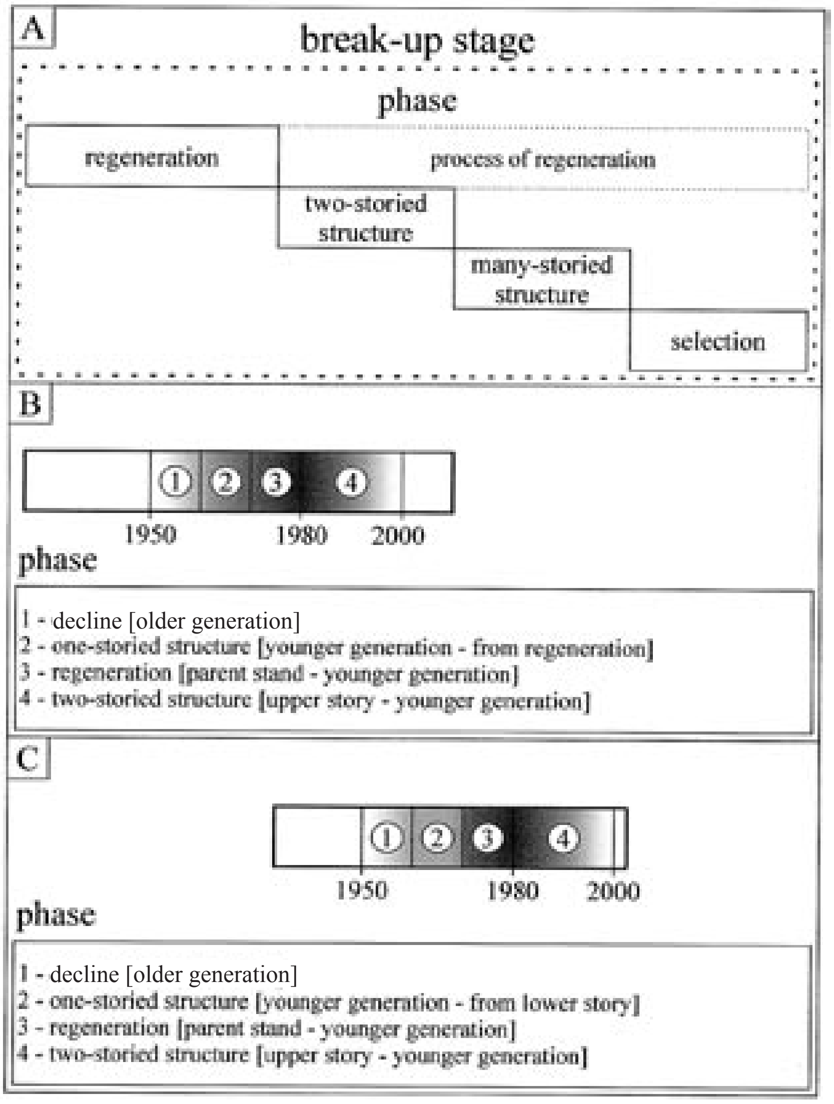

Fig. 7. Hypothetical series of succession changes in the break-up stage after the periods of decline and recovery; A – phases occurring in a typical development cycle according to KORPEĽ (1982); B, C – phases occurring in the decline and recovery periods

[upper layer – younger generation] during the recovery period;

C. the selection phase in the break-up stage – the decline phase [older generation] in the decline period – the selection phase [upper layer – younger generation] in the recovery period.

The portrayal of formation of the remaining untypical phases – decline [younger generation I] and regeneration [parent stand – younger generation] is only possible by using more complicated succession series composed of several successive short phases (Figs. 6 and 7):

A. the decline of fir initiated the decline phase [older generation] in the growing up stage, in the one-storied structure phase (Fig. 6B) or in the decline phase (Fig. 6D). Further intensive mortality of fir trees of the older generation caused formation of a one-storied stand composed of trees of the younger generation (maximum 120–170 years of age) (Fig. 6). The process of fir decline did not stop, including in turn trees of the younger generation, and this led to the next decline phase followed by the one-storied structure phase (about 30–50 years of age) (Fig. 6). Decline of trees in the upper layer did not stop the regeneration process that continued and allowed the creation of younger generation II;

B. the decline of fir initiated the decline phase [older generation] in the break-up stage, in the regeneration phase (Fig. 7B) or in the two-storied structure phase (Fig. 7C). Further intensive mortality of fir trees of the older generation caused formation of a one-storied stand composed of trees of the younger generation (one-storied structure phase [younger generation from the regeneration or from the lower story]), and initiated the regeneration (regeneration phase [parent stand – younger generation]) (Fig. 7). The fir decline process gradually terminated, and this led to formation of a two-storied stand (two-storied structure phase [upper story – younger generation]) (Fig. 7).

The beginning of the first phase occurring in the decline and recovery periods was drawn in the middle of the phase occurring in a typical development cycle according to KORPEĽ (1982) (Figs. 6 and 7). An approximate length of phases occurring in the decline and recovery periods was determined on the basis of the progress of the radial increment of fir (Fig. 4).

Comparison of homogeneity of phase fractions of the forest development periods in the investigated forest ranges

The fraction equality chi-squared test showed that there were no reasons to reject the null hypothesis according to which the per cent participation of phases in the distinguished development periods was the same in both Święta Katarzyna and Święty Krzyż Forest Ranges ($\chi^2 = 2.756$; $df = 3$; $p = 0.4308$).

DISCUSSION

In Poland, similarly like in some other countries of Central Europe, the conception of the forest development stages, phases and periods is one of the dominant standards of forest dynamics (SZWAGRZYK 1988). The main advantage of the phase conception is its great universality that facilitates its application to the analysis of dynamics of forest stands growing at different sites. Besides, the theory of the stand development phases accepts a very diversified spatial scale in which forest dynamics should be analysed. Thus thanks to this flexibility, it is a method joining two opposite extreme opinions according to which the regeneration on a very small or a very large stand area is of the key importance for the dynamics (SZWAGRZYK 1988). The modification of forest development cycle through introduction of additional periods makes the phase conception even more general. And this makes possible to precisely describe stand dynamics during a strong disturbance of development cycle caused by tree decline and recovery.

The results obtained during this study allow to precisely describe the development of stands with fir decline and recovery in the Świętokrzyski National Park. Under different site conditions, and in the case of changes in vitality of other tree species, the conception presented in this paper should be verified, and possibly corrected.

The theory of development phases is used to describe the dynamics of stands of primeval character. In this study the development stages, phases and periods were also used to describe stands growing in strictly or partially protected forest reserves, practically not exploited at least during the last 50 years. High universality and flexibility of the development phase conception also enabled to precisely describe forest dynamics in this situation, although the stands were not of primeval character. An example of utilization of the method of development phases, presented in this paper, confirms its advantages and suggests a possibility of its wider application in forest reserves and national parks.

The radial growth trend of fir presented in this paper is similar to those presented by FELIKSIK (1990), JAWORSKI and his co-workers (1991, 1995, 2000) for fir in the Świętokrzyskie Mountains. After a distinct decrease in fir increment in most sample areas during 1961–1970 and 1971–1980, there was an increase during 1981–1990 (FELIKSIK 1990; JAWORSKI, PAWŁOWSKI 1991; JAWORSKI et al. 1995, 2000).

During the period of fir decline mainly trees of the older generation were dying, which was probably caused by higher amounts of industrial emissions afflicting the crowns of the oldest and usually highest trees (FABIJANOWSKI 1986).

Forest stands in the Świętokrzyski National Park were in the period of decline, and then entered the period of recovery and the period of transformation. Can we be sure that the decline of fir is finished and stands will assume an undistorted development cycle after a certain period of time? The answer to this question is very difficult and complex because, for example, we are unable to predict the future level of factors causing stand weakening. It should also be remembered that there were no significant differences in the per cent participation of untypical development phases in the investigated two forest ranges, situated in two completely different parts of the Łysogóry Mountain Range, between Łysica and Łysiec. The lack of spatial diversification indicates, among others, a vast and strong fir decline process in this mountain range (SIERPIŃSKI 1977; GRANICZNY, UKLEJA-DOBROWOLSKA 1990; GĄDEK 1993). The formation of decline phase [younger generation I] and regeneration phase [parent stand – younger generation] indicates a limited possibility of stands to assume a typical development cycle. Fir trees are unable to reach the age above 200 years, and this causes a shortening and complete deformation of the development cycle. Under such a situation tending treatments aimed at vital, long-lived fir trees are necessary in partially protected reserves. Using cautious cuttings the one- and two-storied stands should be transformed into many-storied and then selection stands where trees produce long and full crowns. Trees of such biomorphologic characteristics are the most resistant, long-lived, and vital (JAWORSKI, ZARZYCKI 1983).

CONCLUSIONS

1. The conception of development phases can be used to describe forest dynamics not only in the case of stands of primeval character but also in the case of forests even more different from the model of a primeval forest where the phenomenon of fir decline and regression occurred.
2. The estimation of the radial increment trend in the Świętokrzyski National Park showed in the case of:
   A. fir: a very strong increment decrease during 1960–1990 and a distinct change from decreasing into increasing tendency since 1980 (1985);
   B. beech:
      I. Of the older generation – a more or less constant radial increment during 1920–1994 (beech trees in the Święta Katarzyna Forest Range), and a slow, but

regular increment decrease especially after 1960 (beech trees in the Święty Krzyż Forest Range).

II. Of the younger generation – a gradual increase in the radial increment during 1940–1990 and its decrease during the last period 1991–1994.

3. After taking into account the progress of the diameter increment of fir and beech the hypothetical series of succession changes, mainly caused by decline and then recovery of fir, were developed. Seven new phases were described in the periods of decline and recovery, occurring in 140 P_6 fields (in total 206 P_6 fields were analysed).
4. It was found that there were no reasons to reject the null hypothesis according to which the per cent participation of the development periods in the Święta Katarzyna Forest Range was the same as in the Święty Krzyż Forest Range, which indicates, among others, that a vast and strong process of fir decline took place in the Łysogóry Mountain Range, between Łysica and Łysiec.
5. In order to improve the description of forest development phases during the periods of decline, recovery and transformation the studies should be continued, especially on permanent study plots. Particularly interesting would be a comparison between results of this study and results of similar investigations carried out in the lower mountainous belt in the Polish, Slovak, and Czech Carpathians and Sudetes.

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Vývojový cyklus lesa s jedlí a bukem v Národním parku Świętokrzyski

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ABSTRAKT: Příspěvek popisuje postup vývojových cyklů lesa zahrnující netypické vývojové periody způsobené odumíráním a regenerací jedle a porovnává procentuální zastoupení jednotlivých fází a period vývoje lesa na lokalitách Svatá Kateřina a Svatý Kříž v Národním parku Świętokrzyski. Vývojová stadia, fáze a periody byly stanovovány v terénu na inventarizačních plochách informačního systému SINUS. Na jednotlivých plochách bylo určováno rozdělení věku, věk porostní úrovně, porostní struktura, tendence objemového přírůstu a tloušťkový přírůst jedle a buku. Jedle až do roku 1960 vykazovala stejnoměrný růst, v období 1960–1985 nastal silný pokles přírůstu. Od roku 1985 nastala u jedle regenerace přírůstu. Buk během celé sledované periody (1890–1994) nevykazoval průkazný pokles tloušťkového přírůstu. Hypotetické řady následných změn porostních fází způsobené odumíráním a regenerací jedle byly navrženy, tyto řady zohledňují tloušťkový přírůst jedle a buku. Bylo navrženo sedm nových vývojových fází mezi periodami odumírání, regenerace a transformace; tyto fáze nejsou v typickém vývojovém cyklu lesa popisovaném KORPEĽEM (1982). Nové fáze lesa byly zjištěny na 140 plochách z celkového počtu 206 analyzovaných. Statistické hodnocení potvrdilo shodu procentuálního zastoupení fází lesa během periody regenerace na lokalitách Svatá Kateřina a Svatý Kříž. Absence statisticky významných rozdílů mezi oběma lokalitami indikuje rozsáhlý a silný proces odumírání jedle v analyzované části národního parku Świętokrzyski (masiv Lysých hor). Další zlepšení popisu vývojových fází lesa během period odumírání, regenerace a transformace předpokládá pokračování studie (zejména na trvalých výzkumných plochách).

Klíčová slova: vývojové cykly lesa; perioda odumírání; perioda regenerace; perioda transformace; SINUS systém; *Abies alba*; *Fagus sylvatica*; NP Świętokrzyski

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