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Vitality of the fir (*Abies alba* Mill.) in the forests of Poland

Andrzej JAWORSKI

1. INTRODUCTION

The fir (*Abies alba*) covers only 2.6% of the forest area of Poland and in spite of the low percentage it is an important component of forests both in the mountains and uplands of central and southern Poland, together with the spruce (*Picea abies*) and the beech (*Fagus sylvatica*). The fir finds optimal conditions for its growth and development and plays an important role in the lower sites of the Carpathians, Gory Swietokrzyskie, and Roztocze (Fig. 1).

Abies alba is decreasing in the forests. HOLOWKIEWICZ (1877) described the Carpathian forests located between the Sola and San rivers as "the land of the fir" (55% cover estimated). MROCZKIEWICZ and TRAMPLER (1964) indicate that the fir occupied 36% of the area of the Carpathians in 1954, while at present it occupies only 26% (TRAMPLER 1980). In certain parts of the Carpathians the proportion of *Abies alba* varies considerably: 3.1% in the Beskid Slaski, 18.9% in the Beskid Maly and Sredni, 7.7% in the Beskid Sadecki, 37.6% in Gorce and Pieniny, 33.5% in the Beskid Niski, 23.1% in Bieszczady, 31.9% in Pogorze, 27.7% in the Gory Swietokrzyskie and 6.9% in Roztocze. Conditions favourable to the development of *Abies alba* in this area are exemplified, apart from its great proportion, by a rich habitat and great abundance (400-700 m³/ha) (JAWORSKI 1979, JAWORSKI and SKRZYSZEWSKI 1986, 1987, JAWORSKI et al. 1988).

In the period of dying out and regression of the fir observed in Europe, the vitality characteristic of the stands with the predominance of the fir occurring in this area is therefore an interesting phenomenon.

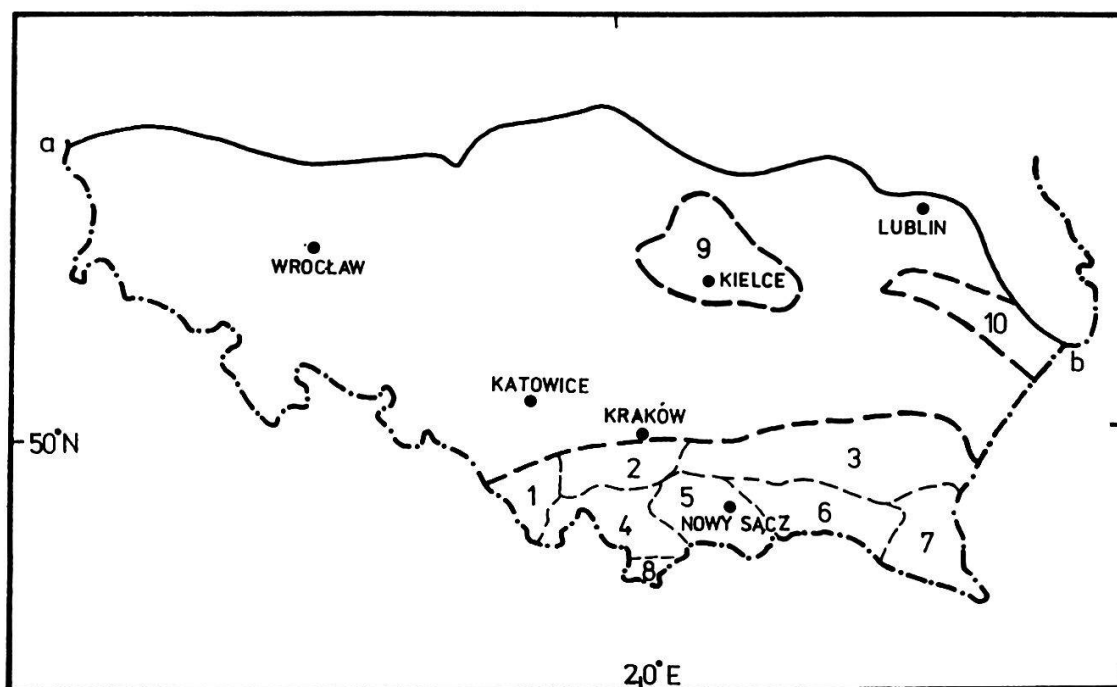


Fig. 1. The distribution of *Abies alba* in geographical regions of Poland. 1 = Beskid Slaski, 2 = Beskid Maly and Sredni, 3 = Pogorze, 4 = Beskid Wysoki, 5 = Beskid Sadecki, Gorce and Pieniny, 6 = Beskid Niski, 7 = Bieszczady, 8 = Tatra Mts, 9 = Gory Swietokrzyskie, 10 = Roztocze; a-b = northern limit of *Abies alba*.

2. METHODS

Sample areas were selected in the way that they could represent habitat types of forests characteristic of the Carpathians and Gory Swietokrzyskie where the fir has always been a substantially dominant or half-dominant species and rarely an admixture. The stands studied were divided into two age categories: 1) stands III and IV of the age category (50-80 years), 2) stands V and older (above 80 years). In the selected stands 15 trees of the Kraft's class II, rarely I and II, were selected. From these trees borings were taken by use of increment auger at 1.3 m height above ground. Then the trees selected were classified with regard to the biomorphological features of their crown. The results of this classification, however, were not taken into account in the present study.

The borings were measured as to the width of the rings from the years 1941-50, 1951-60, 1961-70, 1971-80(85). The mean values of the ten-year-increment of the radius were used in calculating the increment index value (ZAWADA 1981, JAWORSKI and SKRZYSZEWSKI 1986):

$$\text{Index II} = \frac{\text{ring width } d_{1.3}, 1971-80}{\text{ring width } d_{1.3}, 1951-60}$$

$$\text{Index VI} = \frac{\text{ring width } d_{1.3}, 1951-60}{\text{ring width } d_{1.3}, 1941-50}$$

Calculated values of indices II and IV were compared with theoretical indices, considered as minimal values characteristic of good vital conditions of the stands (ZAWADA 1981, JAWORSKI and SKRZYSZEWSKI 1986). Theoretical indices were calculated on the basis of "Yield and increment tables of stands" (SZYMKIEWICZ 1971) for the fir stands occurring in the stand of the second site class. They do not decrease below 0.70 (for index II) and 0.79 (for index IV) and therefore these two values have been rendered critical.

To compare the vitality of *Abies alba* stands studied, the relative vitality indices (W_z) were calculated:

$$W_z = \frac{\text{II} - \bar{\text{II}}}{S}$$

II - increment index characteristic of a given region

$\bar{\text{II}}$ - mean value of increment index II calculated for all units of the analysed age category

S - standard deviation of the index II in a given age category for all regions

This calculation was made separately for both age categories of the stands investigated.

3. RESULTS

3.1. RING WIDTH INCREMENT AND INCREMENT INDICES

Ring width increment and increment indices are accurate and objective criteria of the vitality evaluation of the studied stands.

In the years 1941-50 and 1951-60 mean increment in the studied regions was in younger stands (60-80 years) from 36.1 mm (Bieszczady) to 27.1 mm (Gory Swietokrzyskie), and from 37.4 mm (Pieniny) to 26.4 mm (Beskid Wysocki) (Table 1).

Older stands (>80 years) indicated smaller increments: in the years 1941-50 from 27.7 mm (Bieszczady) to 19.7 mm (Beskid Sadecki), and in the years 1951-60 they reached values approximate to those from the previous period i.e., from 27.0 mm (Bieszczady) to 16.4 mm (Beskid Slaski). In the years 1961-70 a conspicuous decrease in increment was observed. In the younger

Table 1. Mean ring width values of *Abies alba* in 10-years interval and increment indices for the regions investigated.

Region	Current increment in the years (mm)				Increment index		Vitality index
	1941- 1950	1951- 1960	1961- 1970	1971- 1980	II	IV	W _z
Younger stands							
Beskid Slaski	31.0	30.2	19.5	9.2	0.30	0.85	-1.96
Beskid Maly and Sredni	31.6	27.3	19.8	13.6	0.50	0.84	-0.09
Beskid Wysoki	28.4	26.4	18.8	11.5	0.43	0.82	-0.75
Pieniny	35.2	37.4	25.7	16.6	0.44	1.06	-0.65
Beskid Sadecki	30.7	29.4	22.0	15.1	0.52	0.95	0.09
Beskid Niski	32.1	31.2	24.3	15.8	0.56	1.00	0.47
Bieszczady	36.1	35.9	30.3	17.2	0.49	1.07	-0.19
Pogorze	33.6	30.7	28.3	20.2	0.67	0.91	1.50
Gory Swietokrzyskie	27.1	28.3	22.2	15.6	0.58	1.01	0.65
Roztocze	31.3	30.7	23.5	18.7	0.63	1.00	1.12
Older stands							
Beskid Slaski	19.8	16.4	12.1	6.9	0.42	0.82	-0.81
Beskid Maly and Sredni	26.5	22.2	13.7	8.2	0.38	0.88	-1.13
Beskid Wysoki	22.7	19.1	11.9	6.8	0.36	0.84	-1.29
Tatras	20.7	18.5	13.7	9.2	0.49	0.89	-0.24
Gorce	23.7	22.1	13.9	7.5	0.34	0.93	-1.45
Pieniny	22.7	21.7	14.8	10.6	0.50	0.97	-0.16
Beskid Sadecki	19.7	19.6	15.3	11.8	0.63	1.04	0.89
Beskid Niski	25.3	26.3	20.2	13.6	0.55	1.10	0.24
Bieszczady	27.7	27.0	21.8	14.0	0.54	1.00	0.16
Pogorze	23.4	24.6	19.7	14.3	0.59	1.06	0.56
Gory Swietokrzyskie	24.6	24.1	19.9	16.0	0.70	1.01	1.45
Roztocze	22.9	22.5	18.0	15.2	0.69	1.01	1.37

stands it exceeded 30 mm only in Bieszczady, while in the Beskid Slaski, Beskid Maly, Beskid Sredni, and Beskid Wysoki it did not reach 20 mm. In the stands of older age categories it is markedly lower, from 21.8 mm (Bieszczady) up to 11.9 mm (Beskid Wysoki). In the decade 1971-80 there follows further decrease in increment, which in Pogorze alone was over 20.0 mm in the younger stands, but in the stands of older age category it exceeded 15 mm exclusively in the Gory Swietokrzyskie and Roztocze. These values are 2 to 3 times lower than they were at the beginning of the forty-year period under study.

Increment tendencies in the period studied are well characterized by increment indices. In the stands of Gorce, Pieniny, Bieszczady and Roztocze, index IV was always >0.79, which is characteristic of vital stands. In the re-

Table 2. Percentage of investigated stands of *Abies alba* in vitality classes.
(Regions as in Fig. 1, in stand vitality classes number of stands/percentage)

Geographical region (Number of sample plots)	Age classes	Stand vitality classes		
		vital	weakened	strongly weakened
		II>0.70	0.70>II>0.35	II≤0.35
Bieszczady (19)	III and IV	-	5/26.3	1/5.2
	V and older	1/5.3	11/57.9	1/5.3
Beskid Niski (17)	III and IV	2/11.75	4/23.5	1/5.9
	V and older	2/11.75	7/41.2	1/5.9
Beskid Sadecki (19)	III and IV	-	9/47.4	1/5.3
	V and older	2/10.5	7/36.8	-
Beskid Wysoki (28)	III and IV	-	13/46.4	4/14.4
	V and older	-	6/21.4	5/17.9
Beskid Slaski (20)	III and IV	-	2/10.0	4/20.0
	V and older	-	14/70.0	-
Beskid Maly and Sredni (15)	III and IV	-	7/46.7	2/13.3
	V and older	-	3/20.0	3/20.0
Pieniny (4)	III and IV	-	2/50.0	-
	V and older	-	1/25.0	1/25.0
Gorce (6)	V and older	-	3/50.0	3/50.0
Tatras (4)	V and older	-	4/100	-
Pogorze (22)	III and IV	6/27.3	5/22.7	-
	V and older	3/13.6	8/36.4	-
Gory Swietokrzyskie (25)	III and IV	3/12.0	8/32.0	-
	V and older	7/28.0	7/28.0	-
Roztocze (17)	III and IV	2/11.8	4/23.5	-
	V and older	4/23.5	7/41.2	-

mainder stands index IV values <0.79 only in singular cases. Mean index IV values for particular regions, however, are >0.79.

Values of index II point out to a conspicuous turning-point in the increment in the years 1971-80 as related to the decade 1951-60. Vital stands (index II >0.70) still occur in six investigated regions (Table 2). Most of them occur in Pogorze (40.9% of the stands), Gory Swietokrzyskie (40%), Roztocze (35.3%), Beskid Niski (23.5%), Beskid Sadecki (10.5%), and in Bieszczady (5.3%). Only weakened and strongly weakened stands were recorded in other regions. The mean increment index did not decrease below 0.70 (Table 1). It reached values approximate to 0.70 in Roztocze (0.69 and 0.63) and in Pogorze (0.67), though the latter was recorded from younger stands. Analysis of increment values, index values, and values of the occurrence of weakened and

strongly weakened stands indicate that the process of a decreasing vitality of the fir has included the whole area of this species in Poland. A great number of vital stands occurs in southeastern Poland.

3.2. ANALYSIS OF THE VITALITY OF STANDS IN THE REGIONS STUDIED

Beskid Slaski

The stands of this mountain range are strongly influenced by industrial emissions from the Ostrava-Karvina Industrial Centre and from Trinec, both located in Czecho-Slovakia. Decrease in increment dates back to 1940 (ZAWADA 1984). Since 1960 a conspicuous decrease in increment value has occurred (Table 1). The value of index II is one of the lowest in Poland for older (0.42) and younger (0.30) stands. ZAWADA (1984) indicates that the increment of the years 1951-60 cannot be regarded as normal since in those years increment indicated a tendency to decrease. The Beskid Slaski is characteristic of the absence of vital fir stands (Table 2).

Beskid Maly and Beskid Sredni

The decrease in increment in stands of these regions is great (Table 1), which is indicated by the value 0.38 of index II (older stands) and in marked range of the index 0.26-0.59. Much lower but yet marked decrease in increment occurs in younger stands, mean index II value is 0.50 in a range 0.48-0.68 (ZAWADA 1984). In this part of the Carpathians there are no vital firs (Table 2).

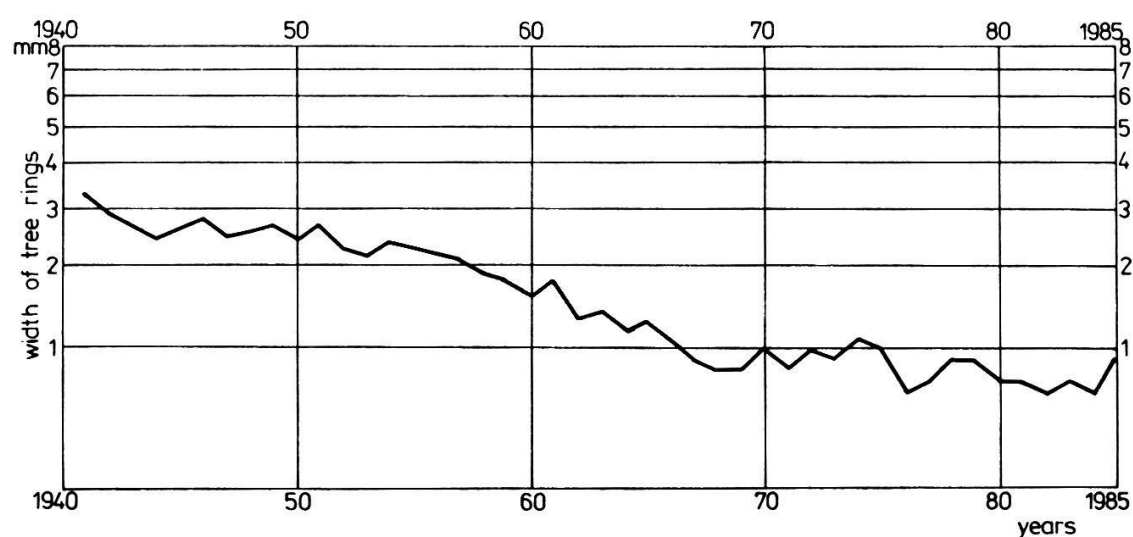


Fig. 2. Mean ring width values for 15 *Abies alba* trees from Kalwaria sample (Beskid Maly and Sredni).

In 1960 (Fig. 2) or even some years earlier (ZAWADA 1984) there was a turning-point in the increment value. The stands in these mountain ranges are influenced by industrial emissions from Silesia and Krakow.

Beskid Wysoki

The decrease in the increment value in the Beskid Wysoki range is great, although it is contained within the value range of indices designating the moderately weakened stands (younger stands 0.43, older stands 0.36) (Table 1). No vital stands have been found (Table 2). Increment values began to fall in 1960 (ZAWADA 1984).

The Tatras, Gorce, and the Pieniny

On the basis of calculated indices it has been found that among all firs investigated vital trees constitute only 11% in Gorce, 20% in Pieniny, and 19% in the Tatras. In all these regions there occurs a marked weakening of fir vitality, which is indicated by the values of index II (Table 1). In the investigated younger stands of Pieniny they reached mean value 0.44. In the Tatras and Gorce the stands of this age category were not included in the studies. In the older stands the values of index II were 0.33-0.66 in Pieniny, 0.30-0.37 in Gorce and 0.41-0.57 in the Tatras (JAWORSKI and SKRZYSZEWSKI 1986).

The process of weakened vitality started first in Gorce in 1960 where it is most advanced. The stands in the Pieniny and Tatras are more vital, although normally vital fir stands do not occur there (Table 2).

Beskid Sadecki

In the Beskid Sadecki the values of index II are 0.32-0.68 and in older stands 0.38-1.03. In the stands examined only 2 (10.5%) were classified vital (Table 2); since 1960 increment value is permanently decreasing. JAWORSKI and SKRZYSZEWSKI (1987) showed that neither climatic conditions nor deformations of tree crowns are the main causes of the decrease in fir vitality. The causes should be looked for in the whole complex of factors, and especially in the atmospheric pollution.

Beskid Niski

In this mountain range, the value of index II is 0.24-0.96 in younger stands and 0.33-0.70 in older stands. Only four stands (23.5%) can be classified vital (Table 2). Weakened stands (64.7%) are dominant. A decrease in increment value was distinct in 1961-70, although some trees indicated weakened vitality as early as in 1951-60 (JAWORSKI and SKRZYSZEWSKI 1986).

Bieszczady

The stands of this easternmost Polish mountain range of the Carpathians exhibit diverse vitality. In younger stands, the value of index II is 0.73-0.46, in

older stands 0.51-0.88. Dominant are the weakened stands (84.2%) (Table 2). A decrease in increment value has been observed since 1961-1970 (JAWORSKI and SKRZYSZEWSKI 1986).

Pogorze

In Pogorze the value of index II is 0.40-0.85 in younger stands, and 0.55-0.78 in older stands. The stands examined are the weakened (59.1%) and vital (40.9%) (Table 2). The stands of Pogorze are the most vital in all the Polish Carpathians. The decrease in increment observed in the hitherto discussed regions from 1961-1970 compared with the earlier period is very low (Fig. 3), although a part of trees exhibited the decrease not only in 1961-70 but also in 1951-60 (JAWORSKI and SKRZYSZEWSKI 1986).

Gory Swietokrzyskie

Among the regions studied, a remarkably high percentage of vital stands was found in the Gory Swietokrzyskie (Table 2). The value of increment index II in younger stands is 0.39-1.24 and in older stands 0.41-1.06 (ZAWADA 1984, JAWORSKI et al. 1988, PAWLOWSKI 1987).

The estimation of vitality of firs in these altitudes cannot objectively be presented by index II value, which refers mainly to the stands in highest altitudes. Many weakened stands occur in lower altitudes. In the Gory Swietokrzyskie National Park ZAWADA (1984) designated seven sample areas in old stands (50-120 years) with index values II 0.41-0.63. In recent years vitality and health condition of stands are constantly decreasing.

Stands located in the eastern part of the Gory Swietokrzyskie exhibit high vitality, estimated on the basis of index II (Table 1). This state probably refers

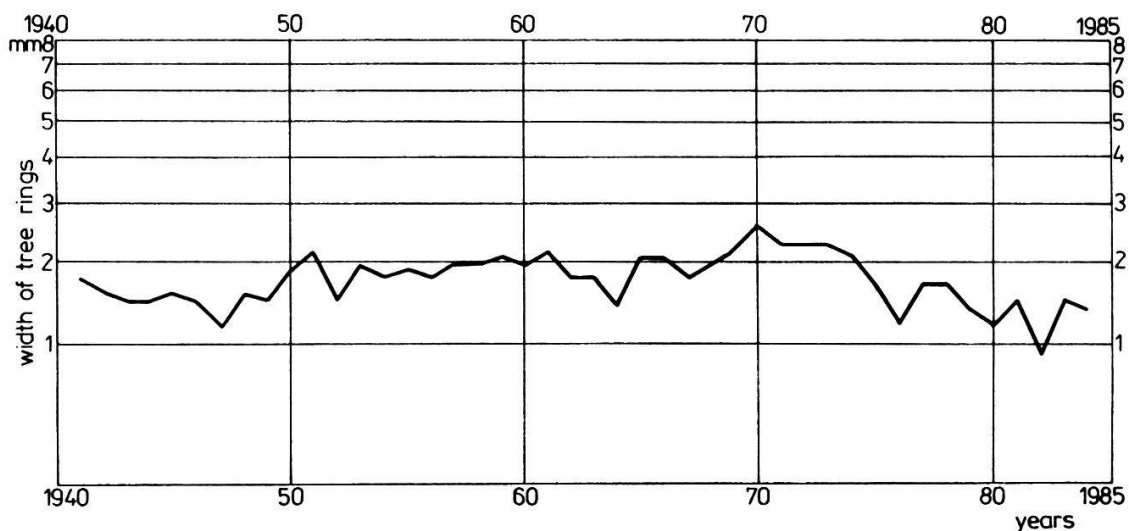


Fig. 3. Mean ring width values for 15 *Abies alba* trees from Brzozow I sample (Pogorze).

to the stands being "under the shadow of industrial emissions" (i.e. protected by the high mountain range of the Gory Swietokrzyskie) and to favourable humidity conditions. The analysis of the increment of two another stands in this region (Figs. 4, 5) indicates that in the years 1973-78 there was a rapid, hitherto not notified, decrease in the width increment of rings. Therefore, the process of weakened vitality of *Abies alba* included the Gory Swietokrzyskie

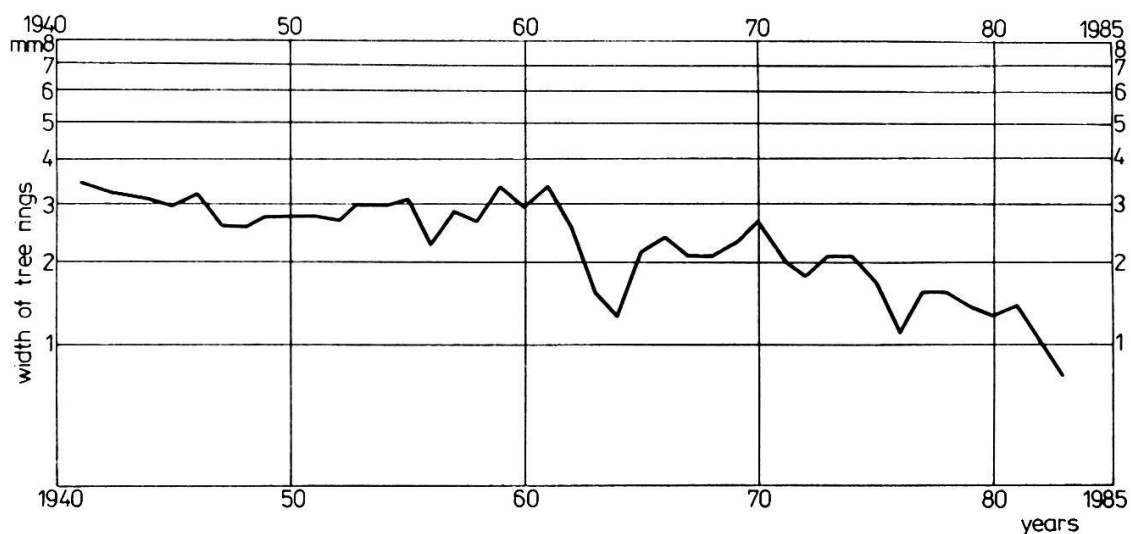


Fig. 4. Mean ring width values for 15 *Abies alba* trees from Skarzysko I sample (Gory Swietokrzyskie).

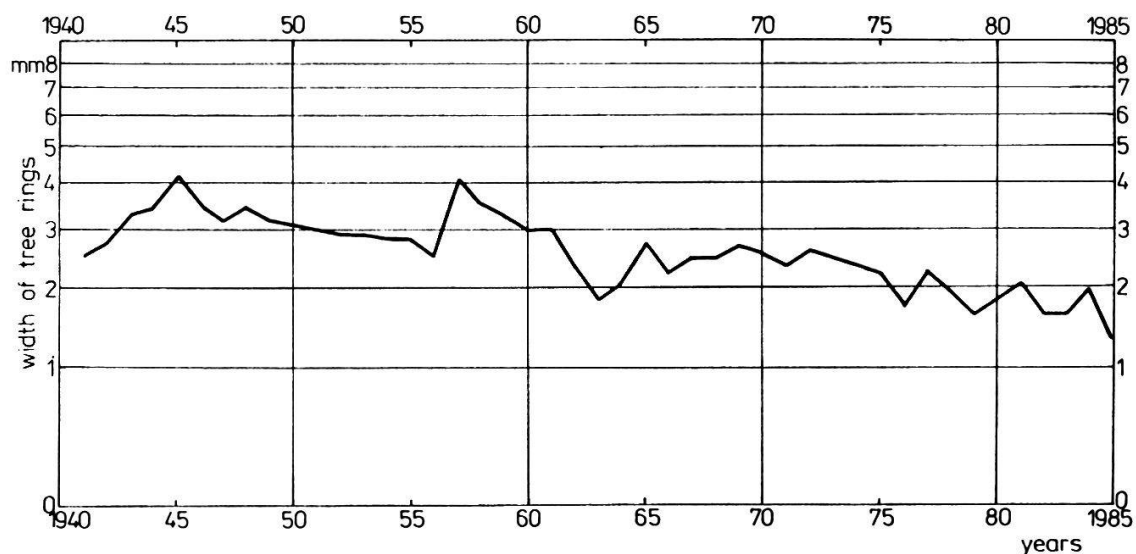


Fig. 5. Mean ring width values for 15 *Abies alba* trees from Skarzysko II sample (Gory Swietokrzyskie).

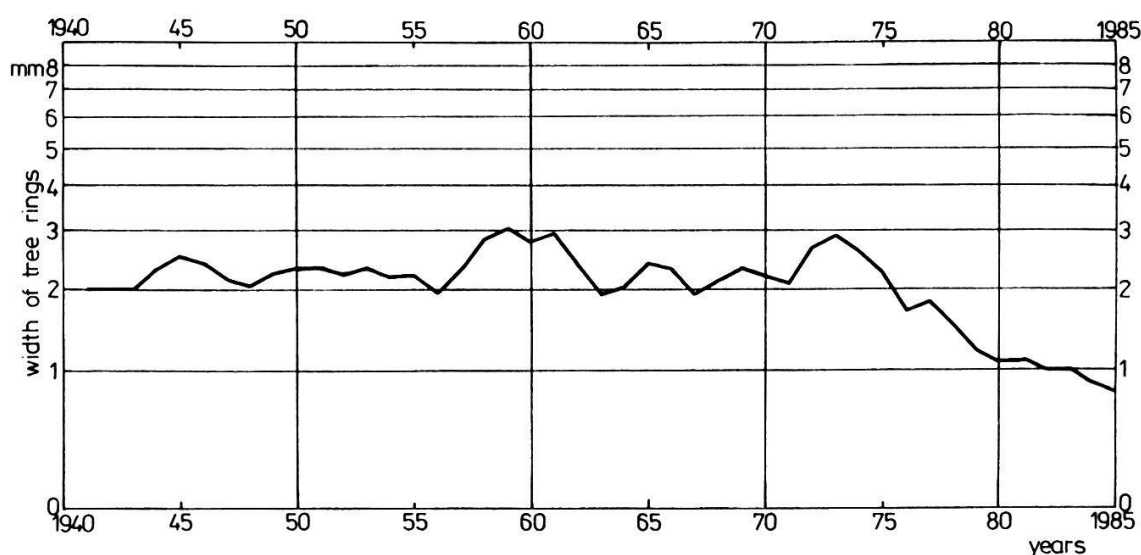


Fig. 6. Mean ring width values for 15 *Abies alba* trees from Zwierzyniec sample (Roztocze).

later than all other regions. In the stands studied by ZAWADA (1984) the increment decreased considerably in the years 1960-80, and in younger stands mainly from 1970-1980.

Roztocze

As it has been given earlier, mean values of the index of increment did not exceed 0.70 (Table 1), but they are among the highest in Poland. The stands are characteristic of diverse vitality. In younger stands the index values are 0.47-0.83, in older stands 0.45-1.06 (ZAWADA 1984, JAWORSKI et al. 1988). The data quoted and those given in Table 2 exhibit no markedly weakened vitality, but gradually decreasing increment since 1960 (Fig. 6).

4. DISCUSSION

The analysis of increment values and increment indices, and also of the occurrence of vital, weakened or strongly weakened stands indicates the process of weakened vitality of the *Abies alba* in the whole range of this species in Poland. Vital stands can be found in the Carpathians in the areas located east of the Dunajec river (from the Beskid Sadecki to Bieszczady in the east), in Pogorze, in the Gory Swietokrzyskie, and in Roztocze. The analysis of increment indices (Table 1) allows an objective comparison of the regions studied. The following younger stands should be considered as more vital than the av-

erage of all regions studied: Pogorze, Roztocze, Gory Swietokrzyskie, Beskid Niski, and Sadecki. The stands of remainder mountain ranges exhibit a low vitality. The weakest vitality is noticed in the Beskid Slaski and Wysoki, Pie-niny, Bieszczady, and Beskid Maly and Sredni.

Among the older stands the most vital occur in the Gory Swietokrzyskie, Roztocze, Beskid Sadecki, Pogorze, Beskid Niski, and Bieszczady. The most weakened are the fir-stands of Gorce, Beskid Wysoki, Beskid Maly and Sredni, Beskid Slaski, and the Tatras (Table 1).

The investigations presented here as well as those done by JAWORSKI and SKRZYSZEWSKI 1987, JAWORSKI et al. 1988) showed that the firs located in the eastern part of Poland, in spite of the generally optimal climatic and soil conditions, are decaying in different degrees. The causes can be found in the whole set of factors, but above all in industrial emissions (FABIJANOWSKI 1986, SCHUTT 1978, SCHWEINGRUBER et al. 1983).

SUMMARY

Based on the increment indices II and IV (Table 1), calculated from the width of the yearly rings of *Abies alba* from 1941-50, 1951-60, 1971-80(85), and on the relative vitality indices (W_z), the vitality of the fir stands located in the Polish part of the range (Fig. 1) was estimated. The stands studied were divided into two age categories: younger stands (50-80 years) and older stands (>80 years) (Table 2). The studies showed that the vital stands are distributed in the Carpathians, in the areas located east of Dunajec river (from the Beskid Sadecki on the west to the Bieszczady on the east), in Pogorze, in the Gory Swietokrzyskie, and Roztocze.

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