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Assessment of the natural resources of European silver fir (*Abies alba* Mill.) in the Polish Sudety Mts.

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Abstract: Data from floristic publications, forest management records, comprehensive questionnaires and original field research were used to assess the silver fir resources in the Sudety Mts. Fir trees older than 50 years were recorded in over 2000 localities but the mean number of individuals per locality was only about 15. The generally low number of fir trees and their considerable dispersion are the major causes of the poor reproduction of the studied species in the Sudety Mts. In that region, silver fir should receive special treatment and, if possible, excluded from logging plans. Current and projected activities concerned with fir protection are described briefly.

Additional key words: number of localities, number of trees, distribution, restitution, protection strategy

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Introduction

Although the majority of forest sites in the Sudety Mts satisfy the potential ecological demands of Silver fir (*Abies alba* Mill.), the species is relatively rare in that area and its participation in forest stands is continually decreasing. The health condition of the most trees is unsatisfactory or simply bad (Boratyński 1991; Mejnartowicz et al. 1994; Zientarski et al. 1994; Boratyński and Filipiak 1997; Boratyński et al. 1998; Barzdajn 1998).

These facts have inspired research on the resources of fir in the Sudety Mts and on the possibilities for restituting this vanishing species on the basis of local populations.

This paper presents a quantitative assessment of the current resources of fir, primarily the number of its populations and their distribution in the Sudety Mts. The age structure and number of trees within localities are also estimated.

Material and methods

The study covered mountain and foothil zone of the Sudety Mts. First, the available data on location of the studied species in that area were reviewed. The data came from floristic publications (Boratyński 1991; Kosiński 2001). This material was supplemented with inquiry data from forest officers, data from forest assessments („stand description") and results of earlier own investigations carried out in the years 1995–1996. The collected information was verified by using of a more detailed questionnaire filled in 1998 by workers employed in Sudetian forest districts

and during field research conducted in 1998–2001. Additional sources of data were complex inventories made in National Park of the Karkonosze Mts (Barzdajn and Raj 2001) and National Park of the Stołowe Mts (Sznajder 2001). The field research was carried out in all forest ranges that reported on the occurrence of silver fir, and the reports were verified with forest rangers. Thus, 854 of the total number of 2575 localities were directly verified. During the field research, the number of silver fir trees in those localities was noted. The updated information on all localities was stored in an Access database, and the localities were marked on maps used by foresters (scale 1:25000), which made it possible to assign the localities to individual geographical units. The geographical division was derived from Kondracki (1998).

In general, the localities were marked with the symbols of forest subcompartments (i.e. the smallest forest units identified on forest maps and in the field, which differ from the neighbouring plots in stand age, species composition, density, tree volume, spatial structure or some other important characteristics). Occasionally, if a plot (subcompartment) was large and fir trees formed several distinct groups within the plot, then each of the groups was marked with an additional digit, for example 345b1, 345b2, etc. Tree age was determined on the basis of forest management reports ("stand description"). Besides, the age of 300 trees was verified using wood samples taken with an increment borer.

Results and discussion

The updated Access database includes 2575 localities, the majority of which (2008) have fir trees older than 50 years. It was more difficult, however, to determine the exact number of trees within the localities. The data came from different sources and from different people. Some information was not precise enough, especially the data on the localities with a larger number of fir trees, where only the approximate percentage contribution of fir (from forest inventories) to a forest stand was specified (±10%). The results of the field research suggested, that this contribution was usually overestimated. Besides, many forest stands were classified (forest inventories) as KO (regeneration class) or KDO (class for regeneration), which are characterized by a low stand density and some degree of natural regeneration. In such cases, the high contribution and large plot size may suggest that the number of fir trees is high, but in practice there are only several or about a dozen fir trees.

Figure 1 presents the results of field observations of the number of trees in 854 randomly selected localities of older fir. The results are alarming as there were on average only 14,5 trees per locality. Forest stands with more than 100 older trees account for only 1% of all verified localities. By contrast, localities with single specimens account for 12% of the total and 63% of localities have less than 10 fir individuals. Since as the total number of localities with older trees is 2008, so the total number of older trees in the Polish Sudety reaches probably only about 32 500. This number is equivalent to about 50 ha of pure fir stands aged 100 years (Czuraj 1997).

The total area covered exclusively by fir of all age classes, estimated on the basis of forestry records from 1981–1990, was about 679 ha (Barzdajn 1998), whereas the corresponding data from 1991–2000 indicate that the area reached 1237 ha (Barzdajn, unpublished data).

Figure 2 shows the estimated distribution of the mean age of fir trees among the localities. If in a given locality clearly two generations of fir trees have developed, the locality is included in two age classes. This applies to only 3% of cases. Most localities with young firs are new (although often situated close to the old ones) and come from artificial plantation. In the Sudety Mts, there are no multi-layered stands composed of trees of various age (selection forest structure) although such stands are considered optimal for fir cultivation. The presented distribution is

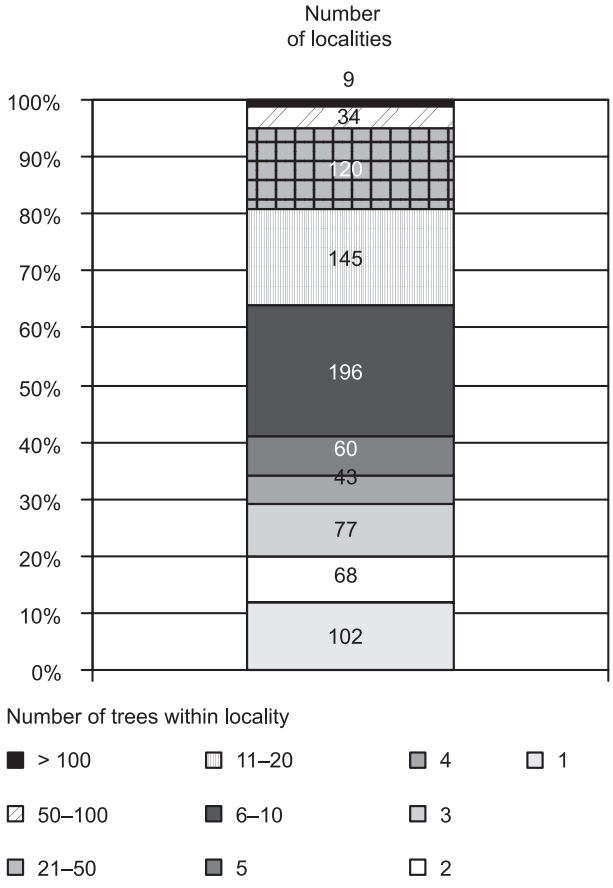

Fig. 1. Distribution of localities with specified number of fir trees (study included 854 randomly selected localities of fir older than 50 years in Sudeten Mts)

very similar to those presented earlier by Boratyński and Filipiak (1997) and by Barzdajn et al. (1999) on the basis of other data. All the mentioned distributions reflect tendencies that are very unfavourable for the silver fir. Field research showed that only up to 15–20% of the local populations with older fir trees in Sudety Mts. have a chance to full reproduction (Filipiak 2001, 2002a). Fir trees are usually found in productive forest stands and are subject to the routine felling plans (hence the low number of fir trees aged >140 years in Fig. 2). Consequently, a marked decline in the total number of fir trees can be expected in the near future. The small number of fir specimens aged 20–60 years is due partly to heavy air pollution in 1970–1990 years but mainly to the fact that foresters convinced that fir is very sensitive to air pollution planted a small number of seedlings in this period (Barzdajn et al. 1999; Barzdajn 2000). Recently, the number of fir localities has slightly increased because of its more intensive planting. However, young plantations are often small and dispersed. This makes it difficult to take proper care of young fir trees and leads to the lowering of their survival rate.

The collected data and the results of field research reveal that the present distribution of silver fir in the studied area has been greatly affected by human activity. The Sudety Mts were relatively early settled by people, as compared with other Polish mountainous regions (e.g. Walczak 1968; Staffa 1985). The various forms of economy developed there earlier, exerting a strong influence on local forests. This issue was discussed in a previous paper (Filipiak 2002b). Today it is difficult to find any forest patch that has never been deforested, even in areas that are not easily accessible. During the last 50 years, the process of eliminating silver fir population was accelerated by strong environmental pollution. Considering that silver fir is regarded as very sensitive to environmental changes, it is no wonder that so few individuals of this species have survived in the Sudety.

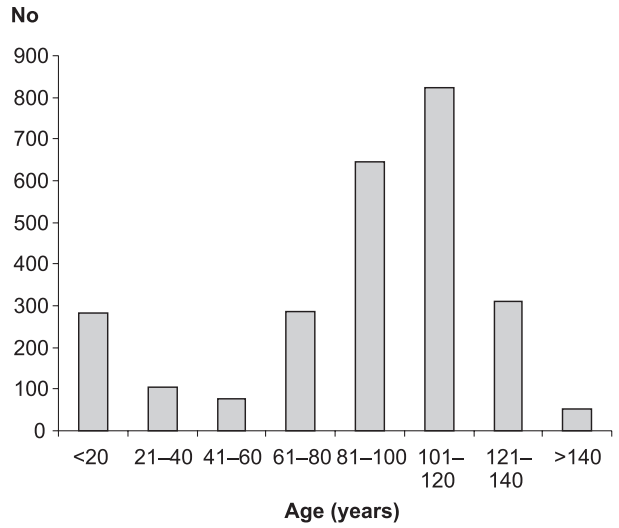

Fig. 2. Number of Sudetic localities with fir trees of specified mean age

At present, silver fir is clearly the most frequent in localities where forest stands are managed less intensively, mainly in those which are not subject to clear cuting. They include:

- valleys of rivers and streams with steep slopes, which are not easily accessible (for example, the Bóbr valley near Siedlęcin and Pilichowice, Szklarka valley in the Karkonosze Mts, Wilczka valley in the Śnieżnik Massif, Waliszowska Woda valley in the Złote Mts, and many others);
- small forest patches covering steep slopes of ravines and landslips (localities found in the foothils zone and intermontane basins; steep mountain slopes; uneven ground covered with rocks and forest patches surrounding large rock outcrops (particularly frequent in the Stołowe Mts and Złote Mts);
- border zone (many localities in the Izerskie, Bystrzyckie, Złote, Bialskie, Stołowe and Opawskie Mts);
- forest patches in the vicinity of military grounds (e.g. a large fortress at Srebrna Góra and underground arms factories in the massif of Włodarz and Osówka in the Sowie Mts);
- park-like forest patches surrounding large castles or palaces (e.g. the woodland around the largest Silesian castle (Książ) and numerous health resorts (e.g. the largest aggregations of silver-fir in the Złote Mts were found in the community forest near one of the oldest Sudetian health resorts (Lądek Zdrój);
- oak forest coppiced for tanneries (the majority of fir trees in the Pogórze Bolkowsko-Wałbrzyskie, mainly near Jawor, Dobromyśl and Stare Bogaczowice);
- stands owned by peasants or former community forest stands, where trees single or in greater numbers were cut for economic reason, without permission and natural regeneration occured (many localities in the Bardzkie, Kaczawskie and Złote Mts; most of localities at low altitudes in the Bystrzyckie Mts and in the Kłodzko Basin, Jelenia Góra Basin, Brama Lubawska and the foothills zone);
- water-protecting forest stands surrounding numerous intake of surface water (gravitational system, without pumps), which for 100 years have fed the water-supply systems of the towns located at lower altitudes.

The types of forest stands listed above usually enjoy (or used to be enjoy) a long period of forest regeneration, which is favourable for silver fir.

Fir trees occur also along the present or former borders between woodland and farmland which suggests that fir seedlings find suitable conditions at field edges.

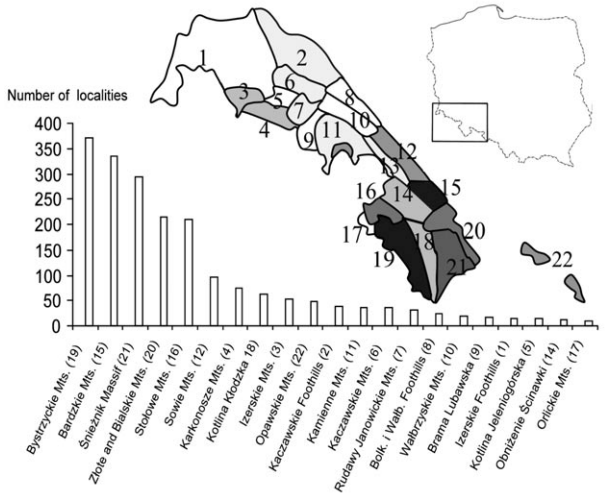

Fig. 3. Number of Sudetic localities with fir trees by subregion (division according to Kondracki 1998)

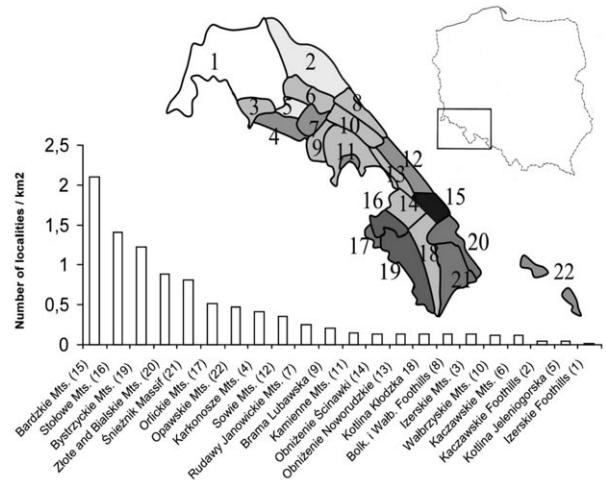

Fig. 4. Number of Sudetic localities with fir trees per square kilometre by subregion

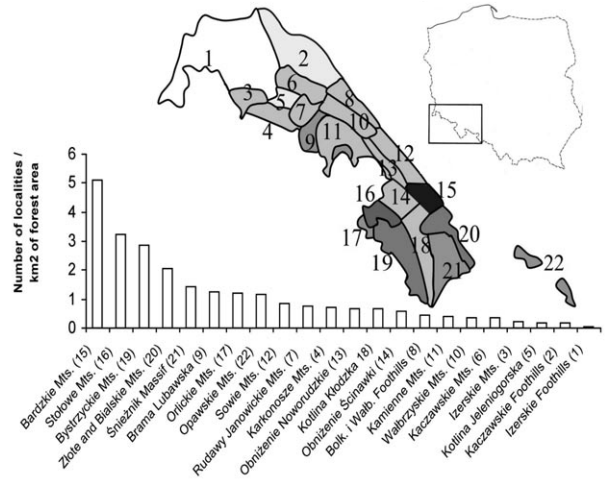

Fig. 5. Number of Sudetic localities with fir trees per square kilometre of forest area by subregion

Single specimens and small groups of fir trees are usually not included in forest management reports, and husbandry practices do not take into account the conditions necessary for natural regeneration of silver fir.

The distribution of silver fir in different parts of the Sudety Mts is uneven. Figure 3 shows numbers of fir localities in geographical units of the Sudety Mts. The number of fir trees per unit of total area (Fig. 4) and of forest area (Fig. 5) was the largest in the Bardzkie Mts, followed by Stołowe Mts and Bystrzyckie Mts, and decreases from the south-west to the north-east. It is difficult to determine which factors contributed to such a distribution of fir trees in the studied area. It may be due to decreasing soil and air pollution from the west to the east, which can be concluded from a report of the Provincial Inspectorate of Environmental Protection (Kulaszka and Kwiatkowska-Szygulska 1999). Besides, historical and ethnic factors could be of some importance. In the late 18th century, after Silesian wars, the border between Austria and Prussia moved, and the Sudety Mts at least the parts that now belong to Poland, were taken over by Prussia. As a result, the economic development of the Kłodzko Basin (south-eastern Sudety), the region economically linked with Bohemia and Austria, was hindered for a long time. The northern and western parts of the studied area, more linked with Prussia, developed faster. Rapid economic development was associated with the introduction of new methods of forest management: a widespread use of clear-cutting and afforestation with fast-growing Norway spruce which severely restricted the occurrence of fir (Zientarski et al. 1994; Boratyński et al. 1998).

The results detained demonstrate that, European silver fir is strongly endangered in the Sudety Mts. and its natural resources are poorer than reported earlier.

The small quantity of silver fir in the Sudety is usually attributed to the high level of environmental pollution in that region, however, in the late 1990's that level decreased considerably and is now in the permissible range. Thus, the pressure of pollution on the environment has greatly decreased. Over the last few years, also the health and vitality of fir have visibly improved (Ufnalski and Filipiak 2002). This is a good sign for the restitution of that tree species in the Sudety. Twenty thousand localities of silver fir can form a good basis for the restitution. It is however very unlikely that fir will increase its share in forests just by natural regeneration, without human help. The main obstacle is the small numbers of trees in fir sites. The isolation and usually small size of local populations of silver fir make cross pollination and genetic exchange very difficult, which has a negative effect on the natural reproduction of this species. In 1999 Suszka and Lewandowski (oral information) in-

vestigated the seeds of firs originating from Sowia Dolina in The Karkonosze National Park and found a very low percentage of full seeds (25–35%) and a high level of inbreeding (70–80%).

Earlier researches (Środoń 1983, Huntley and Birks 1983, Sabor et al. 1996, Skrzyszewska 1999) and especially the latest isoenzymatic studies (Lewandowski at al. 2001) indicate that there is a genetic difference between the Carpathian and Sudetic fir. The same studies also suggest that fir trees in most Sudetic localities (except some documented young plantations) are autochthonous. That is why in the currently implemented fir protection programme, the concept of fir restitution based on Sudetic populations prevails over reintroduction based on Carpathian populations. In practice, the first stage of this programme an inventory of fir resources has already been completed. It is important to supplement the database with new data, especially on newly planted fir stands. The currently realized second stage consists in establishment of seed orchards, which play also the role of clone archives. The Regional Directorate of State Forests in Wrocław sets up such plantations on the basis of grafting shoots collected from earlier selected "preserved trees". The role of those plantations is to preserve the gene pool of old, dying trees and to produce seed under the conditions of panmixis. It is very important to continue and extend this programme. An ideal solution would be to establish clone archives for each mountain range of the Sudety. However, seeds will be produced in those plantations after at least 20–30 years.

The selection of trees for vegetative propagation has been finished but it cannot be excluded that an additional selection will be carried out. In 1999–2003, 245 trees in the Karkonosze National Park and 1587 trees in forest districts of the State Forests Holding were selected. By 2003, over 11 ha of fir clone archives (for seed production) had been established in the Karkonosze National Park and over 36 ha in the State Forests (unpublished data).

Until then, the existing populations should be propagated generatively and the natural regeneration of fir stands should be supplemented with artificial regeneration. For this reason, fir cones should be collected in good crop years, from populations consisting of large number of healthy trees. Moreover, fir trees should be excluded from routine felling plans, and selective felling should favour it, irrespective of their biosocial class and level of crown damage. It should be remembered that fir trees, in contrast to spruce trees, can quickly regenerate even heavily damaged crowns. If solitary fir trees are to be left in clear-cut plots, the neighbouring trees should also be left to protect them, as fir trees are not well adapted to a sudden removal of forest stands around them. It is extremely important to protect naturally regenerating fir stands, mainly against grazing by herbivores (preferably by means of fencing). Shading control and the protection of seedlings against weed, beech and spruce competition are also necessary.

Another important issue is the recording of the tasks performed. In our opinion, each established plot with fir, should be carefully documented to enable both its localization, even after many years, and precise identification (to a forest compartment or group of compartments) of the origin of the seed material used for its establishment. It seems that at least in the first years of restitution, fir trees should not be planted in all the reforested plots. It would be better to introduce them to a smaller number of fenced plots that make it possible to take proper care of the seedlings and to document their history as described above. Proper documentation forms the basis for monitoring the activities associated with restitution and enables later correction of the programme. It is advisable to submit at least some plots with naturally regenerating fir populations to constant monitoring of the development of new generations of fir trees under the influence of local microclimate, insolation, competition with herbs and woody plants, and other biotic and abiotic factors. Ten such experimental plots have already been established, but this number may be insufficient. Similar observations should be conducted also in artificially regenerated fir stands.

Acknowledgments

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