International Conference 'Wind Effects on Trees'
September 16-18, 2003, University of Karlsruhe, Germany

WIND-INDUCED DAMAGE TO POLISH FORESTS AND THE METHODS OF MITIGATING ITS EFFECT

Mikołaj Mikułowski, Wojciech Gil
Silvicultural Department, Forest Research Institute, P.O. Box 61, 00-973 Warsaw, Poland

Abstract

The paper provides brief information about Polish forests and forestry and describes natural growth conditions of trees and stands (climate, soil properties, forest site type).
The proposed classification of wind-induced damage based on many-years data distinguished direct and indirect major types of damage. Two case studies of forest damage caused by wind that occurred in Polish mountains and lowlands are described. Against this background, silvicultural procedures, which are used in Poland to mitigate wind damage effect in forests, as well as measures to prevent damage and restore forests over large deforested areas, are presented.

Introduction

Climatic conditions influence forests and forestry management in many aspects. Long-term means of climatic characteristics such as mean temperatures and precipitation correlate with distributions of plant formations and tree species. Meteorological phenomena such as strong winds, excessive snowfalls have a considerable impact on forest condition (tree and stand damage, deterioration of their physiological state and, in effect, susceptibility to diseases).
Society's expectations of a significant widening of forestry non-wood functions necessitated the reorientation of the previous domination of the raw-materials forest management towards the multifunctional, semi-natural forest management model (see Leibundgut 1973; Schütz 1990, Otto 1993). One of the important goals of the semi-natural forest management is the shaping of stand composition adjusted to the biotope and forest spatial structure resistant to unfavourable natural disturbances, first of all to wind.
The relative stability of forest ecosystems in our climatic zone is first and foremost conditioned by their ability to counteract the extreme weather phenomena, which initiate the chain of forest diseases.
The development of the classification of wind damage to forests proposed in the paper and the identification of regional distribution of wind-risk areas throughout the country will serve to undertake appropriate management decision and silvicultural practices in enhancing forest resistance to the abiotic factors, and thus in mitigating wind risk to forests being one of the major goals of forest management.

Brief information about Polish forests

Forest cover 9 047 000 ha of Poland, or 29.7% of its land area. State-owned forests represent some 84% of the total while those in private hands - covering ca 1 500 000 ha and are mainly (94%) under small-scale ownership. The mean area of such a parcel is ca. 1.3 ha, which makes the rational forest management difficult. This may result in an increase of wind hazard to private forests.
The structure by dominant species shows a preponderance of coniferous species (76.8%), with broadleaves accounting for only 23.2% of the forest area. The clear prevalence of poor coniferous forest habitats is underlined by the permanent character of the even-aged coniferous monocultures occupying them. Although the area of broadleaved stands has been

increasing steadily (by 13% since 1945), the share of these stands remains lower than the potential resulting from the habitat structure (see Gil et al. 2001).
The total standing volume of timber in Polish forest is 1 693 million m^3. The average stand volume for all forests is 191 m^3/ha, though that for the state-owned forests only is higher and equals 209 m^3/ha. The annual volume increment over bark in the years 1994-1996 was 6.1 m^3/ha.

A short history of wind disturbances in Polish forests

The first records about wind disturbances in Poland date back to May 1363, when the catastrophic gales occurred in the Sudeten Mountains.
In the period between the World War I and World War II, the major wind disturbances occurred in southern Poland in the Sudeten and Carpathian Mountains, (1920, 1923, 1925, 1930) and northern Poland in the Knyszyńska Forest (1928). According to the available knowledge they brought down several dozen or so to 200 thousand cubic metres of timber.
Since the World War II, systematic surveys and recording of the extent and intensity of the damage in Poland's forests have started. In 1946–2002, approximately 60 million cubic metres of coniferous and broadleaved timber was windthrown by heavy windstorms and gales, which the hit the whole country more than 40 times. The volume of windthrown timber during a single wind event oscillated between 100 thousand to 15 million cubic metres. Nearly 90% of blowdowns occurred during autumn and winter or early spring.
A systematic collection of data about blowdowns, as well as meteorological measurements allowed for the development of the classification of wind-induced damage and the identification of regional distribution of wind-risk areas throughout the country.

Classification of wind-induced damage to forests

The possibility of quantifying wind-induced damage to forests is the criterion of the proposed damage classification. It is a common practice that heavy wind disturbances in forests are surveyed and recorded only when their economic effects are visible and the extend and the intensity of the damage are measurable (in cubic metres or hectares). This type of damage (e.g. windthrows and windbreaks), which is subject to normal harvesting procedures, shall be classified as direct.
There are other adverse effects of wind disturbances on forests that are not immediately visible and impossible to quantify. The long-distance transport of pollutants, the deepening of physiological stresses in trees (mainly drought), mechanical injuries of the vegetative and generative organs are particularly difficult to survey and measure. However they can have a detrimental impact on forest causing deterioration of forest health condition and in some cases even forest decline. This type of damage shall be classified as indirect. Recognising this, the following classification of damage is proposed:

(1) Direct damage (measurable in m^3 or ha),
(1.1) normal damage: amounts approximating average annual wind damage
(1.2) catastrophic damage: (a) small – from above 1.5-5.0 times the amount of average annual wind damage to below the amount of annual cut, (b) moderate – to three times the amount of annual cut, (c) heavy – above three times the amount of annual cut,
(2) Indirect damage (immeasurable in m^3 or ha).

The class of normal damage and catastrophic damage correspond to the definition of endemic and catastrophic damage by Quine characterised as the result of 'normal' winter storms and strong winds (see Quine 1995).
Annual cut was the criterion used to quantify the damage within the class of direct damage. The classification of damage can be based on the criteria other than annual cut, for instance on the percentage of downed trees, percentage of stem 'loss', percentage of both stem and canopy damage, percentage of broken or uprooted canopy stems (see Everham III 1995). These criteria can facilitate the assessment of losses to forest ecosystem, however annual cut appears more useful in forest management.

Regional distribution of wind-risk areas in Poland

The need of delineating areas with different risk of wind damage to forests results from two major causes: the high variability of climatic conditions in Poland and prevalence of Scots pine in species composition of forests. The northern Poland are under the influence of coastal and maritime climate (Baltic Sea), the extensive tracks of central Poland's lowlands are open to the westerly winds from the Northern Sea and Atlantic Ocean while southern Poland has mountainous climate with typical foehn winds. The climate becomes more continental from the west to the east. Under the influence of these two types of climate the weather is highly variable. Forest based on artificial regeneration with one prevailing species and varying weather conditions are particularly vulnerable to wind impact (see Slodičák 1995).
Different risk of wind disturbances to forests was the criterion of distinguishing three wind-risk areas (see Zajączkowski 1991). The first area with the lowest risk of wind disturbances encompasses the central zone of lowland Poland. The second area encompasses the moraine belt of the Pomerania and Mazurian Lake District in the north, the Sudeten and Carpathian Foothills in the south and the Świętokrzyskie Mountains. The third area with the highest wind risk comprises the narrow coastal belt of the Baltic Sea in the north and the Sudeten and Carpathian Mountain in the south.
Both the classification of wind-generated damage and regional distribution of wind-risk areas are the basis to employ appropriate silvicultural management further discussed in the paper.

Regional examples of wind damage to forests

(1) The Piska Forest – direct catastrophic forest damage

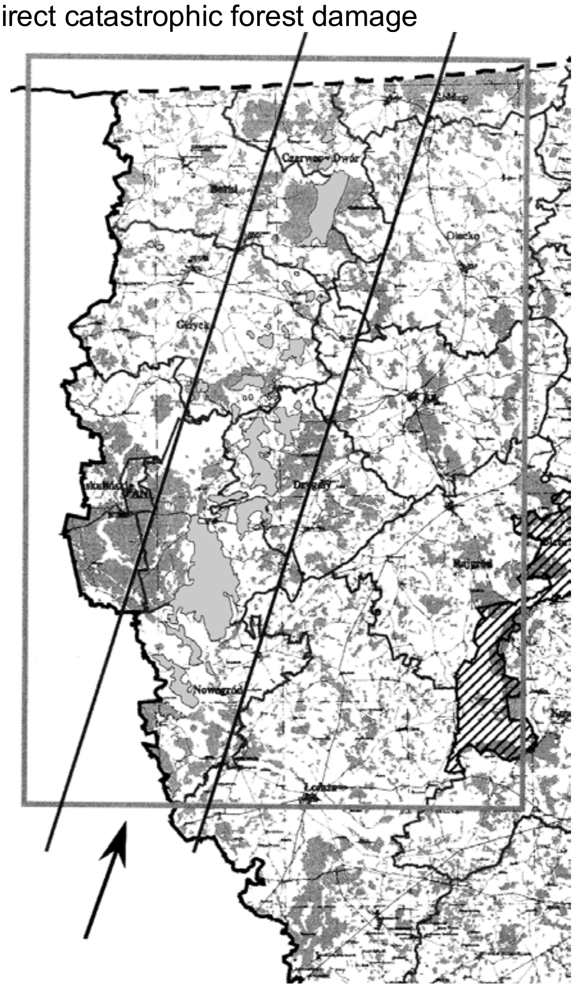

Fig. 1. Wind-damage forests in NE Poland (4 July 2002), light grey – windbreaks

The Piska Forest (north-east Poland) has suffered acute forest damage from the winds. In the past centuries, the major wind disturbances causing forest damage occurred in 1580, 1702 and 1833, 1839, 1867, 1888 (see Uggla 1965). After the World War II, the Piska Forest experienced several dozen or so winds storms of which the heaviest ones occurred in 1999 and 2002. The heaviest forest damage was on 4 July 2002, when 3 million 755 thousand cubic metres of timber was brought down by a storm in a very short time (in less than 1/2 hour). The wind destroyed forest in a narrow belt of 11 km in width and 130 km in length irrespective of age (Fig. 1).
The main cause of forest damage of 4 July 2002 was the cold front that occurred between two air masses causing storms accompanied by a sudden violent squall wind from the S-W direction (Mikułowski 2002). The wave motion of the cold front that passed over the Piska Forest on 4 July and favourable conditions for intensive convection were similar to the wind episode of 15 July 2001 in the forests of Pomerania. In such a synoptic situation, the wind damage in Polish lowland forests usually occurs in summer (Ożga 2002).

(2) Sudety Mountains – indirect forest damage

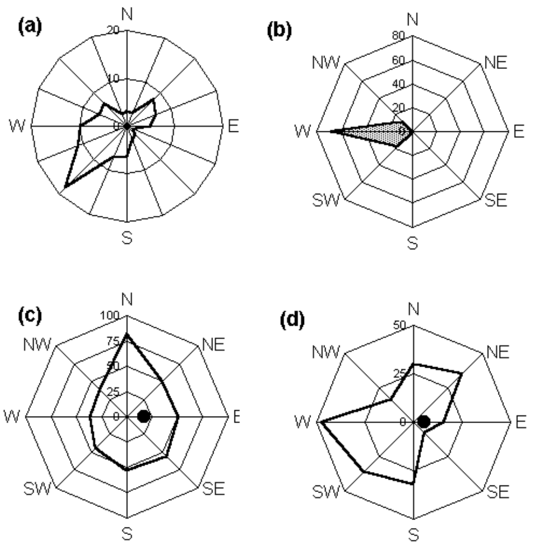

Fig. 2. Wind impact on regeneration in the Sudeten Mountains: (a) rose of winds on the Szrenica Mt. (1362 m a.s.l.), (b) direction of stem injures, (c) percentage of injures of stems and twigs on different slope exposition, (d) breakage of stems and twigs on different slope exposition. Black point in fig.(c) and (d) - cluster planting.

A large-scale forest dieback in the Sudeten Mountains started in 1979-1980, first in the West Sudeten at higher elevations, later also at lower elevations. Forest decline in this region have occurred as a result of the high concentrations of several pollutants (mostly SO_2 and NO_x) and their combination with other mainly climatic-related types of stress. The climate in this region is characterised by prevailing westerly winds (Fig. 2a), high annual precipitation amounting to 1760 mm (see Sobik, Migała 1993), thick and long-term snow-cover and high frequency of mists. Felling of the dead standing trees proceed over an area of 15 thousand hectares which accounts for more than 8% of the Sudeten forests. Timber volume harvested in Sudeten forest districts in 1980-1996 increased from the West to the East.

Timber volume [$10^3 m^3$] harvested in Sudeten forest districts in 1980-1996

West	→						East
1164.1	1016.2	775.9	674.1	562.9	561.5	720.3	365.5

The basic silvicultural and management problem faced by forest researchers was restocking and stabilisation of young stands established on the cleared areas. The stabilisation of young stands is difficult due to specific climatic conditions in the Sudeten Mountains.
The studies concerning wind impact on young regeneration in the West Sudeten Mountains (see Mikułowski et al. 2001) demonstrated that injuries (reduction and discolouration of needles, wounds of stems and twigs, and crown asymmetry) found on trees were from SW to NW i.e. directly exposed to prevailing winds. More than 70-80% of injuries were connected with the W direction irrespective of slope exposition (Fig. 2b), however the percentage and degree of all injuries to trees were connected with slope exposition (Fig. 2c, d). Injuries in the regeneration planted in cluster arrangement (Rottenpflanzung) are smaller than in the regeneration established by a regular planting pattern (Fig. 2 c, d).
The above-presented data highlight the negative impact of wind on forests and stand regeneration in the Sudeten Mountains.

Silvicultural methods of mitigating wind effects on forests

The windfirmness of trees depends on the interaction of few factors: strength of the wood; shape and size of the crown; extent and depth of the root system linked with soil and site properties, and shape of the bole (Gardiner, Quine 2000). At the stand level, wind resistance can be enhanced by shaping stand composition, spatial and biosocial structure, as well as its health condition. (see Zajączkowski 1991). At the forest complex level, the stand size, spatial and temporal order, as well as the location of stands within a forest complex are the major factors contributing to stand resistance. With a view to enhancing wind resistance of stands and to mitigating the adverse wind effects, a number of silvicultural practices in the stands in the wind-risk areas are recommended.

(1) Choice of species
Planting is the most common means of restocking in Poland. The choice of species is determined by site conditions, which are mostly poor coniferous habitats. Species should only be selected from those, which are well adapted to the site and local climate. Special consideration should be paid to use patches of more fertile microsites allowing the introduction of broadleaves as admixture species on poor sites (see Gil 1995; Rozwałka 2003).
The expansion of broadleaved tree species, which is commonly observed in our forests, favours a spontaneous development of the lower layer even on poor soils. This natural process facilitates the tending of sites and stands and influences the rate of the regeneration process of deformed stands. The expansion of broadleaves will serve to meet the basic principle of the semi-natural cultivation of forests aimed to obtain the stands with the richest species composition and structure, relatively resistant to wind damage.

(2) Planting density
According to the principles set up in the Silvicultural Principles in force, the obligatory planting density in Poland ranges from 8 to 10 thousand bare-root seedlings of Scots pine per hectare.
In the wind-risk areas, wider spacing is more advantageous. It reduces tree slenderness (h/d ratio) and the lowers the crown position on the stem. As regards Scots pine, the most widespread species in Polish forests, the choice of spacing is always a compromise between enhancing stand resistance to wind and reducing technical quality of wood. Under specific conditions such as wind-risk areas III and II, the decision to reduce the initial density to less than 8 thousand seedlings per hectare is reasonable.

(3) Improvement and final cuttings
Taking into account the planting densities used in Poland, it is imperative to apply improvement cuttings in attaining wind resistant trees and stands.
The spatial structure of stands plays an important role in increasing stand resistance to the adverse impact of meteorological factors such as wind and snow. Appropriate distribution of stands within a forest complex enhances stand resistance to wind. Equally important is the

distribution of individual trees in a stand, however even distribution of individual trees in the stand at various developmental stages operating in a “classical” model of forestry does not seem necessary. The Harz Mountains are an the example that the group structure of the mountain stands ensures their stability (see Otto 1994). Such a spatial structure of stand can also be used in lower elevations and lowlands. The negative impact of wind can be reduced by applying the improvement cutting as one of the methods enhancing the resistance of pine stands. Group thinning is an important element of the near-to-nature forestry management resulting in relative stability of structure the pine forests (see Zajączkowski 1994). The pine stands undergo the following developmental regularities:

1. the group structure of regeneration in the manifestation of natural developmental tendencies (see Zajączkowski 1990),
2. there is no excessive number of the “future” tree, i.e. such which can form the stand that is most stable and of the highest quality in terms of its future development,
3. the group structure of stands can increase stand productivity and does not reduce the technical quality of trees (see Zajączkowski 1994).

The group thinning aimed at stand stabilisation promotes natural group structure of stands, so it is based more on tree populations than on individual trees selected in accordance with the criteria acknowledged by silviculturists. This method of forest cultivation has been accepted by foresters and used in forest practice (see Rozwałka 2003). However, the application of the group thinning is efficient under condition that tending treatments will not be neglected from the very earliest stages of stand development.

The risk of wind damage to forest does not impose the choice of the given cutting system that should be adjusted to the requirements of the dominant species in the recommended (target) stand composition.

Silvicultural Principles (see Rozwałka 2003) put special emphasis on minimizing wind risk in selecting the cutting system with special consideration taken of natural factors such as prevailing wind direction, topographic features and soil properties, stand health condition and spatial structure. Technical aspects of applying the cutting system among others the size of the cutting area, regeneration interval, cutting intensity, stand age, height and slenderness of trees, etc.

(4) regeneration in the deforested areas in the mountains

As regards deforested areas in the mountains, the conception of forests regeneration bases on the shaping of spatial structure of the stands near timberline (see Sokołowski 1928; Myczkowski 1964; Szymański 1986). Under extreme mountain conditions the conception of group regeneration is found applicable during the establishment of plantations (see Mikułowski 1995). The spatial and age structure obtained in this way can ensure stand stability (see Schönenberger et al. 1990).

Conclusions

Stand resistance to winds is determined by appropriate silvicultural methods applied to a stand at various stages of its development, including species composition, planting density, systematic improvement cuttings and the choice of the most suitable cutting system.

Adjustment of species composition to site conditions is the fundamental postulate of the semi-natural forest management, the application of which increases stand resistance to wind. Undoubtedly, the postulate to increase species richness in the stands must take account of the natural characteristics of the habitats occupied by forests in Poland, which are the poorest habitats at this geographical latitude in Europe (coniferous forest habitats occupy ca 60% of the forest area).

The enhancement of the resistance of pine stands that prevail in Poland can be attained by applying tending treatments i.a. group thinning.

Under extreme climatic mountainous conditions the conception of shaping their spatial structure using cluster planting is found applicable during the establishment of plantations.

Acknowledgements

We want to thank Katarzyna Machnacz Mikułowska for helpful comments and translation.

References

Everham III E. M. 1995: A comparison of methods for quantifying catastrophic wind damage to forests, In: Wind and Trees. Ed. by M. P. Coutts and J. Grace, Cambridge Univ. Press, pp. 340-357

Gardiner B.A., Quine C. P. 2000: Management of forests to reduce the risk of abiotic damage -- a review with particular reference to the effects of strong winds, IUFRO conference 'Wind and other abiotic risks to forests', Joensuu, Finland, August 1998, Forest Ecology and Management, 135, No. 1-3, pp. 261-277

Gil W. 1995: Przestrzenne mikrozróżnicowanie gleby leśnej- jego charakter i związki z drzewostanem (Spatial microdifferentiation of forest soli – its character and links with tree stand, in Polish with English summary), Sylwan R.139, No. 4, pp. 33-39

Gil W., Głaz J., Michalak R. 2001: The place of Continuous Cover Forestry among the Silvicultural Systems in Poland. Preliminary Proceedings (ed. by Gadow v. K., Nagel J., Saborowski J.), International IUFRO Conference "Continuous Cover Forestry. Assesment, Analysis, Scenarios." 19-21 Sept. Göttingen, Germany, pp. 79 – 89

Leibundgut H. 1973: Rationalisierung und naturnahe Waldwirtschaft, D. Forst-u. Holzwirt., 28 Jhrg., No. 8, pp. 365-368

Mikułowski M. 1995: Nowe formy odnawiania lasu w Sudetach Zachodnich (New methods of forest regeneration in West Sudety Mountains, in Polish), Prace IBL, Seria B, No. 25/2, pp. 251-264

Mikułowski M., Kliczkowska A., Zajączkowski P., Migała K., Sobik M. 2001: Opracowanie warunków klimatycznych wybranych nadleśnictw Sudetów Zachodnich dla celów typologii leśnej, hodowli lasu I leśnej regionalizacji nasiennej (Study of climatic conditions of the selected West Sudeten forest districts for silviculture, forest typology and seed production, in Polish), Technical Report of the General Directorate of State Forests Manuscript, pp. 1-58

Mikułowski M. 2002: Problemy zagospodarowania lasu na terenie klęski wiatrowej z lipca 2002 r. w północno-wschodniej Polsce (The problem of forest management after July 2002 wind damage in NE Poland, in Polish), Prace IBL, Ser. A, No. 937-943, pp. 129-132

Myczkowski M. 1964: Struktura i ekologia zespołu świerka *Piceetum tatricum* u górnej granicy zasięgu w Tatrzańskim Parku Narodowym w Dolinach Stawów Gąsiennicowych i Pańszczycy (The structure and ecology of the spruce association *Piceetum tatricum* at the upper limit of its distribution studied in the valleys dolina Stawów Gąsiennicowych and Pańszczyca in Tatra National Park, in Polish with English summary), Ochrona Przyrody, No. 30, pp. 51-105

Otto H.J. 1993: Der dynamische Wald-Okologische Grundlagen des naturnahen Waldbaues, Forst u. Holz., Jg. 48, No. 12, pp. 331-335

Otto H.J. 1994: Okologisher Waldbau. Walddynamische prozesse bei fichte und kiefern im rahmen waldbaulicher rationalisierung, Teil I, Der Wald, Jg.44, No.11, pp. 364-367 and Teil II, Der Wald, Jg.44, No.12, pp. 408-411

Ożga W. 2002: Meteorologiczne warunki powstawania szkód wiatrowałowych w lasach Pomorza w lipcu 2001 roku (Meteorological conditions of wind damage to the forests in the territory of the State Forest Holding in July 2001, in Polish with English summary), Sylwan, No 5, pp. 83-87

Quine C. P. Assessing the risk of wind damage to forests: practice and pitfalls. In: Wind and Trees. Ed. by M. P. Coutts and J. Grace. Cambridge Univ. Press pp. 379-403

Rozwałka Z. 2003: Zasady Hodowli Lasu (Silvicultural Principles, in Polish), DGLP, pp. 1-159

Schönenberger W., Frey W., Lanenberger F. 1990: Ökologie und Technik der Aufforstung in Gebirge, Anstalt für das forstliche Versuchwesen, Berichte 325, pp. 1-58

Schütz J.-Ph. 1990: Heutige Bedeutung und Charakterisierung des naturnahen Waldbaus. Schweiz. Zeitschr. Forstwes., No. 8, pp. 609-614

Slodičák M. 1995. Thinning regime in stands of Norway spruce subjected to snow and wind damage Ed. by M. P. Coutts and J. Grace. Cambridge Univ. Press, pp. 436-447

Sobik M., Migała K. 1993: The role of cloudwater and fog deposits on the water budget in the Karkonosze Mountains, Swiss Meteorological Institute, Alpex Regional Bulletin, No 21, pp. 13-15

Sokołowski M. 1928: O górnej granicy lasu w Tatrach (Timber Line in Tatra Mountains, in Polish), Kraków, pp. 1–188

Szymański S. 1986: Ekologiczne podstawy hodowli lasu (Ecological principles of silviculture, in Polish), PWRiL, Warszawa, pp. 1-461

Uggla H. 1965: Puszcza Piska, w: Dzieje lasów, leśnictwa i drzewnictwa w Polsce, (Piska Forest, in: The history of forests, forestry and timber utilization in Poland, in Polish, with English summary), PWRiL, Warszawa, pp. 565-576
Zajączkowski J. 1990: Stabilisierende Gruppendurchforstung in Kiefernbestanden Forstarchiv, Jg. 61, No. 1, pp. 39-40
Zajączkowski J. 1991: Odporność lasu na szkodliwe działanie wiatru i śniegu (Forest resistance to wind and snow damage), in Polish, Wyd. Świat, Warszawa, pp. 1–224
Zajączkowski J. 1994: Biogrupy drzew w drzewostanach – możliwość i celowość ich wykorzystania przy prowadzeniu trzebieży (Tree biogroups in forest stands – possibilities and rationale for their use at thinnings, in Polish with English Summary, Prace IBL, Seria A, No. 778, pp. 5–38