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Assessment of Hazard from Damaging Wind Gusts in the Siedlce Area

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ABSTRACT

The average daily values of wind speed and wind gust speed in the years 2001–2018 in Siedlce were analyzed. In the study area, the frequency of individual wind directions was determined and, according to criteria set by the Government Centre for Security, the frequency of hazards from damaging wind gusts was evaluated. The following wind gusts were considered: >20 m/s, 25 m/s and 35 m/s. It was found that, in the Siedlce area, the prevailing wind direction was west-south-westerly (WSW), and the average annual wind speed in the long-term study period was 2.99 m/s. March, April and May were the months when the highest speeds of maximum wind gusts (>35 m/s) were recorded. Extreme wind gusts the speed of which poses a hazard to the environment, national economy as well as human life and health, occurred in both the cold and warm seasons of the year.

Keywords: wind direction, wind speed, wind gusts, hazard.

INTRODUCTION AND OBJECTIVE

The Polish legislator defines a natural disaster as a natural hazard or technical failure which poses a threat to the lives or health of a great number of people or property on a large scale, or to the environment in a large area. Moreover, both assistance and protection may be offered only through using extraordinary measures undertaken by various bodies and institutions cooperating with one another and assisted by specialist services and formations led by a uniform body (Journal of Laws 2017 item 1897). The natural disasters which may result in the state of emergency include climatic phenomena (Chojnacka-Ożga, Ożga 2018a, b). The definition of a meteorological extreme phenomenon refers to its threshold value which, when exceeded, results in visible destruction posing a threat to humans, as well as the technical infrastructure of the affected area (Lorenc, 2012a). Due to its location in the temperate climatic zone which has a transitional character, Poland is exposed to a clash between maritime and continental air masses, which may result in an occurrence of a variety of climatic hazards. Their likelihood and intensity are changing as a result of climate change, including global warming (Kundzewicz and Gerten, 2015). According to Lorenc (2005), wind gust intensity is affected not only by pressure drop to even below 970 hPa in the centre of moving low-pressure area and passing of a cold or occluded front, but also formation of horizontal pressure gradient of more than 1.5 hPa/100 km. When wind gusts exceed 17 m/s, the pressure gradient value is higher that 2.5 hPa/100 km. Damaging winds are, e.g. the winds connected with cyclonic activity during the cold season, foehn winds linked with the mountain orographic barrier, winds occurring during storms (mainly whirlwinds) and straight-line winds. A wind gust is a rapid increase in strength of wind of more than 5 m/s relative to the average 10-minute speed (WMO, 2012). In the whole area of Poland, both winter high winds and whirlwinds are a possibility. However, the degree of threat posed by them is different. Hurricane-force winds destroy infrastructure elements, such as buildings, communication routes or power line networks. In construction, negative wind influences include various strains on building structures. Other adverse effects of wind include snowdrifts, movement through thermal insulation of buildings, pushing of water inside spaces, possibility of negative pressure formation inside buildings, suction of fumes from flues and, on a larger scale, pollution spread (Żurański et al., 2011).

In forested areas, the wind-related damage leads to economic losses associated with windfalls (Adamowicz et al., 2016; Pawlik, 2015). Due to the specific character of the flow of air masses, which is terrain-related (landform, type of ground cover, protection from land obstacles, etc.), wind speed is highly variable in temporal and spatial terms. This, in turn, translates into differences, in any location, between the properties of the local wind and general characteristics of the wind occurring in the region. The objective of the work was to assess the speed of strong wind gusts which may constitute a hazard to human life and health as well as cause infrastructure damage in the Siedlce area.

MATERIALS AND METHODS

The work is based on the results of observations recorded at the Meteorological Station in Siedlce in 2001–2018. The data include average daily wind speeds in m/s, wind gusts and wind directions during 24 hours. The percentage share of wind directions in the study years are presented using the wind rose as a radar chart, and numbers of days with wind gust speeds falling into individual ranges were determined according to the classification set out by the Government Centre for Security (Rządowe Centrum Bezpieczeństwa – RCB) (Lorenc 2012). The classification includes three levels of hazard from strong wind (Zagrożenia, 2012). The first level includes the speeds of wind the gusts of which exceed 20 m/s with predicted results including damage to buildings and their elements, losses due to windfalls, damage to trees and road communication disruptions. The second level hazard occurs when wind gusts exceed 25 m/s leading to serious damage to buildings, uprooting of trees (windthrow), breaking of tree branches, communication disturbances and destruction of power line networks. The third level refers to the events of wind gusts exceeding 35 m/s. The destruction resulting from such events includes destroyed buildings, blowing off of rooftops, and extensive damage to tree stands, and it poses a serious hazard to life. In each month, the frequency of wind gusts at each level of hazard in the years 2001–2018 was determined.

RESULTS AND DISCUSSION

Wind rose analysis demonstrated that in the Siedlce region in 2001–2018, west-south-westerly wind (WSW) was the prevailing direction (13%) followed by westerly (W) and south-westerly (SW) directions (9% for each) (Fig. 1). The least frequent direction was northerly (N), north-north-easterly (NNE), north-easterly (NE), east-north-easterly (ENE) and north-north-westerly (NNW) direction (4% for each).

The average annual wind speed for 2001–2018 was 2.99 m/s (Fig. 2). The highest average annual wind speed in the study period was recorded in 2004 (3.62 m/s), being the lowest in 2018 (2.66 m/s). The highest average monthly wind gust speed of 35 m/s was recorded in May (Fig. 3). The gust speed was also high in March, as it reached 26 m/s. In contrast, the lowest value of average wind gust speed was recorded in June (20 m/s).

The greatest number of days when wind speeds were in excess of 20 m/s was recorded in January (13 days), being the lowest in May, August, October and December (2 days in each month) (Fig. 4). The occurrence of high wind speeds during the cold season of the year is a normal characteristic of the climate of Poland connected with the general atmospheric circulation. The origin of hurricane-force winds in the summer, which are treated as natural disasters, is in

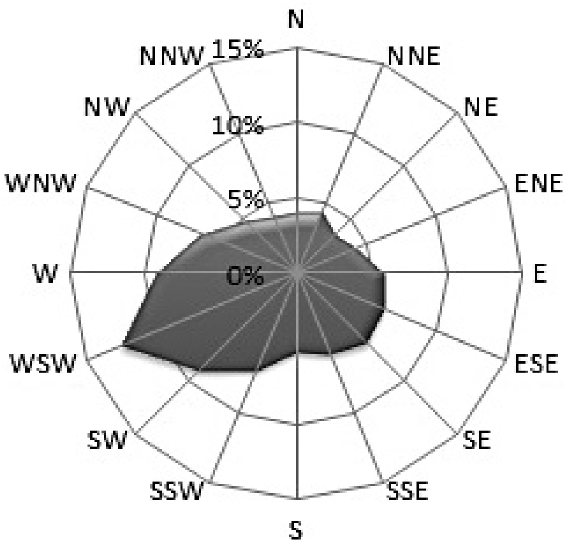

Fig. 1. Wind rose for Siedlce in the years 2001–2018

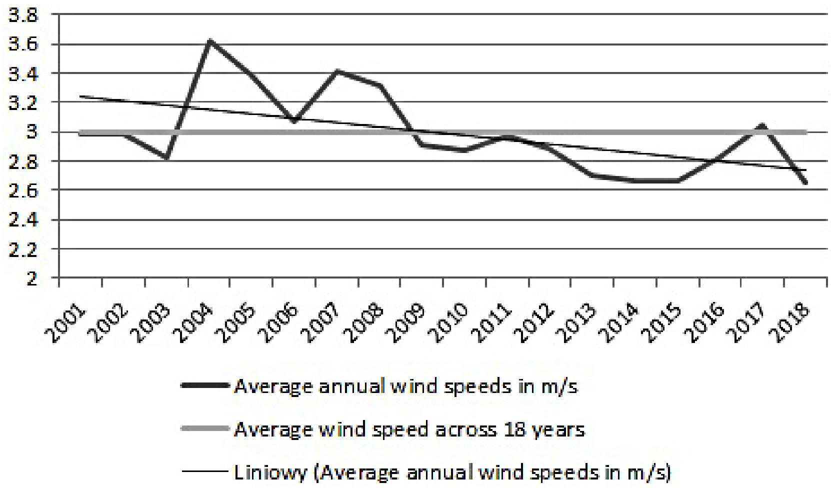

Fig. 2. Average annual and average annual long-term (2001–2018) wind speeds in the Siedlce region

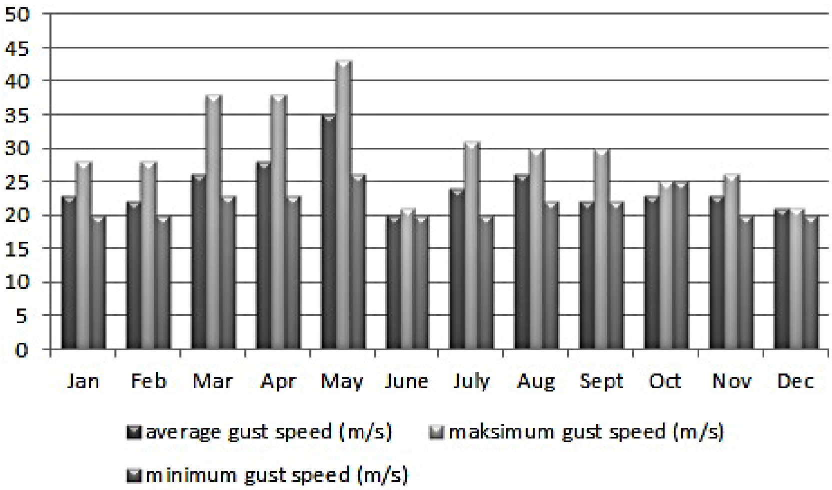

Fig. 3. Average, minimum and maximum monthly wind gust speeds in the Siedlce region

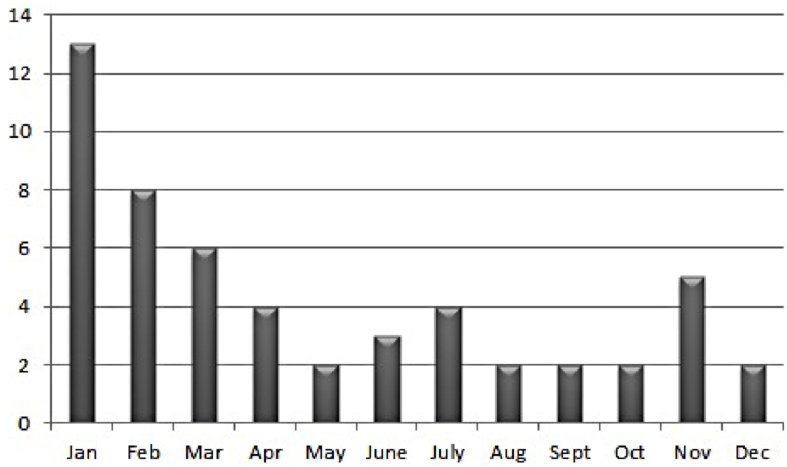

Fig. 4. The average number of days with wind gusts in excess of 20 m/s in the Siedlce area

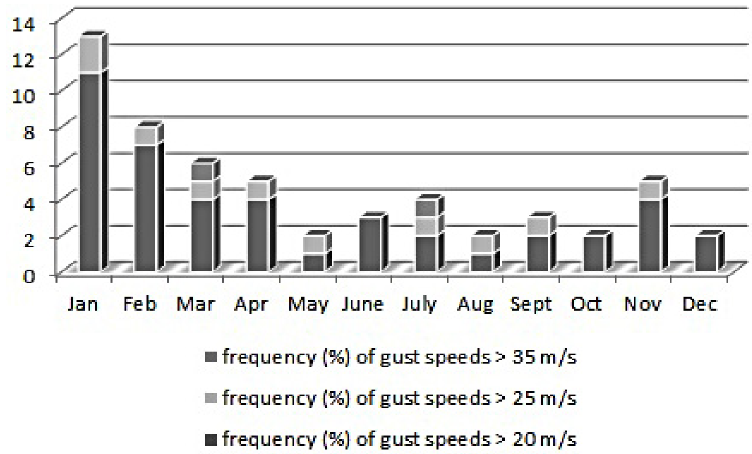

Fig. 5. Percentage share of the frequency of wind speeds exceeding 20 m/s, 25 m/s and 35 m/s in individual months in the Siedlce region in 2001–2018

general more complex. The damage in this season of the year may be incurred by whirlwinds (Lorenc 2012). Figure 5 shows the frequency of wind gusts within the ranges set out by the Government Centre for Security. The higher wind gust speed, the greater the risk of natural emergency. The occurrence of wind gust speeds exceeding 20 m/s poses a major threat to the safety of humans. It causes massive damage to buildings – shingles are blown down, lighter objects are lifted in the air, unprotected structures under construction are at risk, and large tree limbs break off. The highest frequency of this type of wind was recorded in January (11%), being the lowest in May and April (1% in each month). The wind the speed of which exceeds 25 m/s incurs extensive damage to buildings, towers and chimneys, it throws and uproots shallowly-rooted trees, makes driving a passenger car more difficult, as well as excites substantial swaying of power lines which, when covered in hard rime or glazed ice, may snap due to excessive weight applied. This type of wind in the Siedlce area was the most frequently recorded in January (2%) followed by February, March, April, May, July, August and November (1% in each month). The wind speeds in excess of 35 m/s are highly destructive, as they affect the whole infrastructure, uproot trees, carry heavy objects which, due to their weight, inflict additional damage e.g. to car bodies, and break glass. Such gusts are direct threat to life. In the Siedlce area, this type of wind gusts was recorded in March and July with a frequency of 1%. Chmielewski et al. (2013) reported that the extent of damage is related to high wind intensity and whirlwind-related data such as the vortex path, length and width and, first and foremost, intensity. The damage is inflicted on structural constructions, buildings, vehicles, trees, and power line networks; both human life and health are at risk under such conditions. In turn, Gengfeng et al. (2014) claimed that wind gusts weaken trees, because they cause great stress in the timber structure and destructively affect the rooting system. An insight into the mechanisms leading to an occurrence of adverse weather phenomena, assessment of their influence on forests, and risk management in relation to the effect of such phenomena constitute the basis of constructing a strategy for economy functioning, including forestry.

CONCLUSIONS

The most frequent wind direction in Siedlce in 2001–2018 was the west-south-westerly, the average annual wind speed in the study period being 2.99 m/s. Maximum wind gust speeds (above 35 m/s) were recorded in March, April and May. Extreme wind gusts the speed of which posed a threat to the environment, national economy as well as human health and life were recorded in the study area. Such events were recorded in both the cold and warm season of the year. The most frequent wind gusts had speed values in excess of 20 m/s, with the events when wind gust speeds exceeded 35 m/s being the rarest. For operational purposes, it is recommended to devise a classification of extreme wind speeds according to the likelihood of their occurrence and anticipated effects on the economy at various spatial scales, including the local scale.

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