**SHORT COMMUNICATION**

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# Monitoring of spruce stands in the Czerwona Woda river catchment of the Stołowe Mountains National Park

*Paweł Strzeliński*[1], *Mieczysław Turski*

Poznań University of Life Sciences, Faculty of Forestry, Department of Forest Management, Wojska Polskiego 71C, 60-625 Poznań, Poland, e-mail: strzelin@up.poznan.pl

## Abstract

In the spring of 2017, Stołowe Mountains National Park started a research program related to the protection of water resources. The research program was started because of, among others, the growing problems of water resources and the dying of spruce trees. One of the projects commissioned by the Park was ‘Monitoring the impact of renaturisation and hydrological status on changes in the biomass of trees and stands’. The monitoring covered spruce stands growing along the main watercourse of the Park (the Czerwona Woda). As a part of the study, three rectangular surfaces (from 0.45 to 0.50 ha) and 10 circular areas (0.04 ha each) were established. On fenced rectangular surfaces, 10 model trees were selected using the Draudt method. They were monitored using hemispheric cameras (changes in crowns), dendrometers (changes in the circumference of stems) and minirhizotronami (changes in the root layer). In addition to the measurements of all the trees on the surface, imaging with terrestrial laser scanning and hemispherical images was done.

The data and results presented in this work were created as a result of the implementation of a project financed from funds related to the forestry fund of the State Forests National Forest Holding.

## Key words

tree biometrics, model trees, Kraft classes

## Introduction

Stołowe Mountains National Park was established in 1993, among others, to protect the existing ecosystems and landscape values. Surface area in the Park is dominated by forest ecosystems, which occupy over 90% of its total area, of which about 80% are spruce stands. The vast majority of these are areas transformed anthropogenically, with artificially introduced spruce, originating from outside this area. The condition of forest ecosystems is also strongly influenced by the not-so-favourable water conditions, resulting from a small number of watercourses and frequent periods of drought. The result of this is more and more problems with the health condition of spruce stands, including numerous, ever-growing sockets of spruce bark-beetle.

Due to this situation, in the spring of 2017, the Stołowe Mountains National Park began preparations for launching a wide-ranging research program related to the protection of water resources. One of the topics accepted for implementation was ‘Monitoring of

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the impact of renaturisation and hydrological status on changes in the biomass of trees and stands'. It was assumed that the planned research will be the registration of the 'zero state' of tree biomass and stands, that is, the state before the start of activities related to the restoration of the main watercourse in the Park (Czerwona Woda).

The waters of this stream, together with its basin, feed not only a large part of the park ecosystems, but are also the main source of water for the towns of Karłów, Batorów and Szczytno. Therefore, it was assumed that periods of drought, and hence, large disturbances in the water volumes of the Czerwona Woda catchment, have a direct impact on the condition of the spruce stands.

In further stages of the research, the control of changes in the biometric features of the stands along the Czerwona Woda stream and the assessment of the impact of the hydrological state on forest ecosystems in the basin of this stream are planned.

The results of the research would be used to assess the impact of the planned renaturalization of the stream on forest ecosystems in the catchment, in the context of wood biomass growth, and consequently, to assess and assess the possibilities of increasing $CO_2$ absorption and carbon retention.

## Material and methods

In accordance with the arrangements and consultations conducted with the Park management and employees of the Faculty of Forestry and the Faculty of Environmental Engineering and Spatial Management of the University of Life Sciences in Poznan, research related to monitoring the impact of renaturisation and

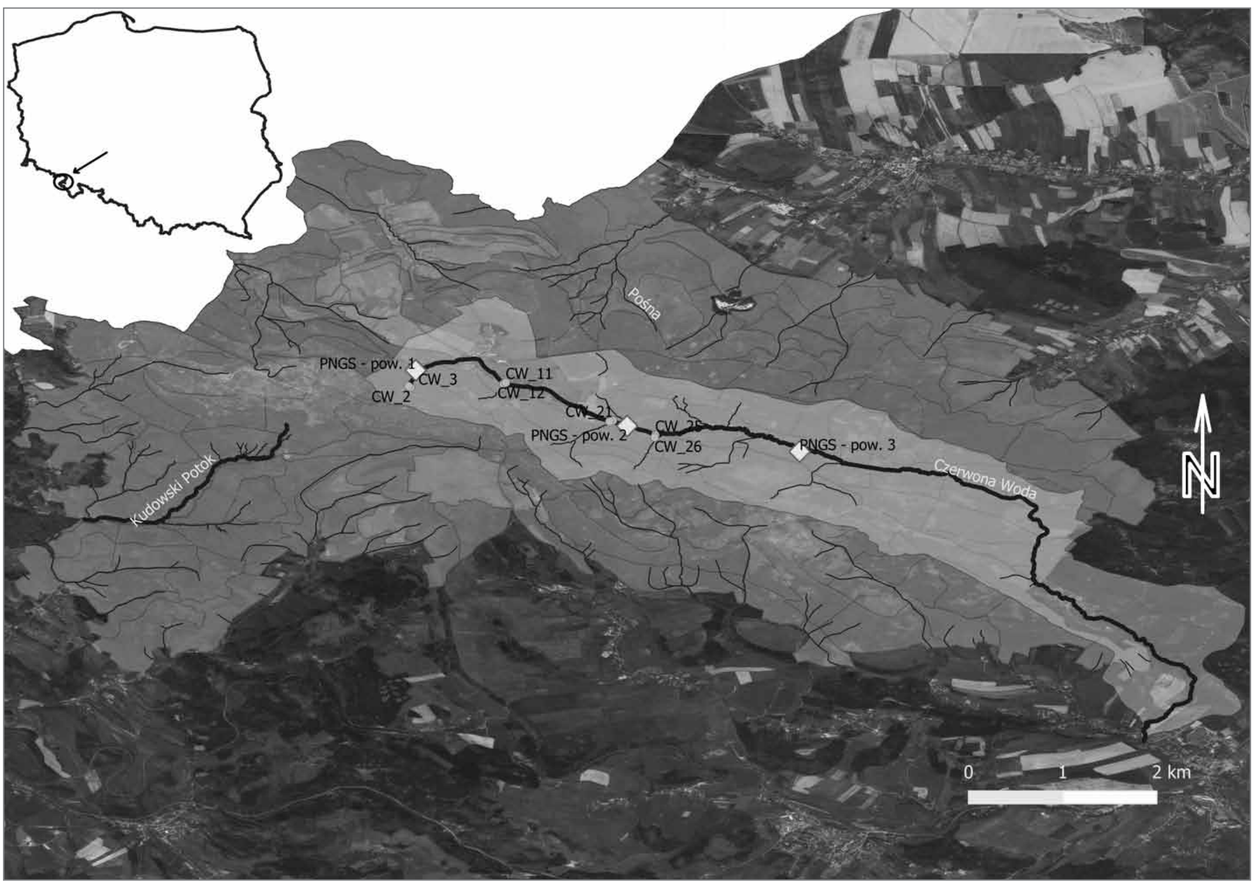


**Figure 1.** Location of research areas along the Czerwona Woda stream, against the background of the borders of the Stołowe Mountains National Park and the Czerwona Woda catchment

hydrological status on changes in the biomass of trees and stands was limited to the main watercourse of the Park, that is, the Czerwona Woda. The research was located in the stands directly adjacent to the Czerwona Woda stream in two groups of research areas: 3 rectangular surfaces (A1 – 4500 $m^2$, A2 – 5000 $m^2$ and A3 – 5000 $m^2$) and 10 circular areas of 400 $m^2$ each (B1, B2, B3 , B4, B11, B12, B21, B22, B25 and B26) (Fig. 1).

The rectangular surfaces with the longer adjacent side (if possible, depending on the shape of the Czerwona Woda shoreline) to the watercourse were to meet the following criteria:

A1 – an area with a negligible influence of the potential re-hydrization of the watercourse, adopted as a reference for the rest – above the village of Karłów

A2 – the area being, among others, under the influence of the retention reservoir – between the village of Karłów and the retention reservoir

A3 – area in the middle of the watercourse

Each of the surfaces was to meet the following methodological assumptions: single-species stand (*Picea abies* [L.] H. Karst), one-story and unadulterated (acceptable single specimens of other species). The physiognomy of the stand was to be representative of the immediate environment (mainly in terms of crown density), the area could not be crossed by roads and watercourses (without reservoirs and water banks), with a minimum of 200 trees covered by measurements (measurements did not include dead trees, scrap and tipping).

On the research surfaces, all the trees were permanently numbered (with paint) and border trees were marked by marking the place of measurement of the breast height (letter T). On each of them, measurements were made using traditional terrestrial methods on live, standing trees. Measurements and observations covered the following features: breasts of all trees with species designation, altitude of all trees on circular surfaces and 20% of trees on rectangular surfaces with measurement of the height of the crown seating and determination of the biosocial position (according to Kraft). These surfaces, after their demarcation and measurement work, were fenced. This was necessary due to the installation of fixed measuring devices. Measurements carried out in October and November 2017 allowed to establish a number of features characterizing both single trees on trial plots as well as tree stands. These were the following biometric characteristics:

$d_{1.3}$ (cm) – Breast height
$g_{1.3}$ ($m^2$) – Breast height cross-section
$v_s$ ($m^3$) – Thickness of shot
$v_q$ ($m^3$) – Thickness
h (m) – Height
$l_c$ (m) – Length of the crown
$H_L$ (m) – Height of the stand calculated with Lorey formula
$d_g$ (cm) – Average cross-sectional breast height of the stand
N – Number of trees
$G_{1.3}$ ($m^2$) – Height breast cross section of the stand
$V_s$ ($m^3$) – Thickness of shots of the stand
$V_q$ ($m^3$) – Thickness of stand

On each rectangular surface, the dimensions of 10 model trees were calculated according to the Draudt method.

On circular surfaces, scanning was performed ‘from the centre of the surface’, and on rectangular surfaces, 5 scans (the first in the geometric centre of the surface, and another 4 in the vicinity of its corners). When scanning area means, it was assumed that the scanner will register the stand in the entire available angular range, that is, 360 degrees in horizontal and 300 degrees in vertical. The scanner resolution was set to ½ full capabilities. The colour registration option was started. The FARO Focus 3D X 130 scanner was used to scan the research areas in the Park.

Hemispherical images were also taken on the surfaces. The Park used a method of shifting measuring points, taking pictures at 9 points (Strzeliński, 2008). According to this assumption, the tripod with the photo set was set every 4 m. The centre of the surface coincided with the place where the scanner was set.

Another methodological assumption was to perform 3 replicas on each of the 9 measuring points (3 hemispheric images). Therefore, a total of 27 photos were taken on each circular surface, and 135 photos on each rectangular surface.

The basic methodological assumptions concerning the taking of hemispherical photos, which were used during measurements on the research surfaces in the Park, were used by Weiss et al. in 2004 and verified during field work, among others, by Strzeliński (2006), Kałuża and Strzeliński (2008), and Strzeliński (2008).

In the Park, a set consisting of a SLR digital camera ('SLR') – Canon EOS 5D (matrix 12 MP) and a Sigma 8 mm F3.5 EX DG CIRCULAR FISHEYE lens was used to take hemispherical photos. The software Gap Light Analyzer (v. 2.0) was used to analyse the hemispherical images (http://www.ecostudies.org/gla). As a result, the following parameters were obtained characterizing the light conditions on the tested surfaces: openness (%), LAI 4 Ring, LAI 5 Ring and radiation [(mol/m2/day) and (%)] – direct, indirect and total. For calculations LAI (Leaf Area Index), the so-called 'LAI 4 Ring' (calculated for the ring between the zenith and an angle of 60° above the horizon) and 'LAI 5 Ring' (for the angle between the zenith and 75° above the horizon).

On three selected surfaces (rectangular surfaces: A1, A2, A3), sensors were installed that supported monitoring of the changes:

– in root systems – using minirhizotrons similar to BTC 100X (Bartz Technology Corporation, Canada) (1 pcs/area)
– in the increment of tree trunks to the thickness – using dendrometers (10 items/area)
– in the crown layer – using hemispheric cameras (10 pcs/each)

Cameras and dendrometers monitor changes on the so-called model trees (10 items/area), representing the variability of tree height and thickness on the research plot. Minirhizotron was placed at the so-called central model tree, representing the average height and thickness of trees on the research area, and they would be analysed after providing data from the first measurement period. Unfortunately, too late assembly of the above sensors in relation to the planned dates of implementation did not allow the use of the collected data in the final analyses. This stage was postponed to the spring of 2018.

This chapter presents a shortcut of the results of measurements made on type A surfaces, where the sensors were set (hemispheric cameras, dendrometers and minirhizotrons).

Dimensions of the model trees were calculated using the Draudt method (Grochowski, 1973). Mounted cameras and dendrometers monitor the changes taking place on model trees. In addition, for model trees marked with the number 6 (central model tree representing the average height and thickness of trees on each surface), a minirhizotron was placed.

The smallest mean values of biometric features (Tab. 1) characterizing a single tree were recorded in the area of A1 (the insignificant impact of potential restoration) slightly higher on the area A2 (area under the influence of the retention reservoir), and the largest on the area A3 (middle part of the watercourse). The smallest disproportions between the analysed features on the area A1 and A3 were recorded between the average tree height (about 22%) and the largest between the average thickness (both the thickness of the shot and the thickness was almost twice as large as on the area A3). The greatest variability was found in the thickness of trees (over 50%) and their boudoir sections (over 47%), and

**Table 1.** Basic statistical characteristics of trees growing on type A surfaces

| Characteristic | Plots | | | | | |
|---|---|---|---|---|---|---|
| | A1 | | A2 | | A3 | |
| | average | coefficient of variation (%) | average | coefficient of variation (%) | average | coefficient of variation (%) |
| $d_{1.3}$ (cm) | 35.7 | 25.3 | 40.5 | 24.3 | 46.8 | 24.4 |
| $g_{1.3}$ ($m^2$) | 0.11 | 49.6 | 0.14 | 47.5 | 0.18 | 47.2 |
| $v_s$ ($m^3$) | 1.26 | 55.9 | 1.81 | 53.8 | 2.51 | 51.5 |
| $v_q$ ($m^3$) | 1.26 | 56.0 | 1.81 | 53.9 | 2.50 | 51.6 |
| h (m) | 25.5 | 9.8 | 28.5 | 14.1 | 31.1 | 9.3 |
| $l_c$ (m) | 13.6 | 23.5 | 14.9 | 25.6 | 18.6 | 23.0 |

the lowest variability concerned height (less than 10% on A1 and on A3, and 15% on A2) and crown length (less than 25%).

The lowest average height of the stand (Tab. 2) was found in the area of A1 (26.35 m). This average is 3.69 m higher on the area A2 and by 5.53 m on the area A3. The average cross-section breast height is similarly shaped. On the surface A1 is 36.8 cm, and on subsequent surfaces, it increases by almost 14% and 31%, respectively. The smallest number of trees in the area 1 ha has been demonstrated on the area A2 (332 trees). On the surface A1, there were 104 trees more, and on the surface A3 – 112 trees. The breast section diameter of stands was similar: the smallest area was on A2, slightly larger on A1 and the largest on A3. The smallest thickness of trees per 1 ha (both shot and thickness) was found in the area of A1 (around 550 $m^3$), by more than 50 $m^3$ in area A2, and over 100 $m^3$ in area A3.

**Table 2.** Basic characteristics describing the stand on type A plots

| Characteristic of stand for 1 ha | Plots | | |
|---|---|---|---|
| | A1 | A2 | A3 |
| $H_L$ (m) | 26.35 | 30.04 | 31.88 |
| $d_g$ (cm) | 36.8 | 41.7 | 48.2 |
| N (pcs.) | 436 | 332 | 444 |
| $G_{1.3}$ ($m^2$) | 46.39 | 45.33 | 47.59 |
| $V_s$ ($m^3$) | 549.49 | 601.92 | 654.29 |
| $V_q$ ($m^3$) | 548.29 | 601.07 | 654.46 |

Table 3 shows the percentage share of trees classified to particular Kraft classes. Trees prevailing both in the area A1 and A3 are 90%. The largest number of trees dominated (19%) grew in the area A2.

**Table 3.** Percentage share of trees in Kraft classes on type A plots

| Plots | Percentage share of trees in Kraft classes | | | | | |
|---|---|---|---|---|---|---|
| | I | II | III | IVa | IVb | Va |
| A1 | 19 | 34 | 37 | 10 | 0 | 0 |
| A2 | 15 | 44 | 22 | 12 | 2 | 5 |
| A3 | 17 | 44 | 29 | 10 | 0 | 0 |

## Conclusions

Launched in 2017, the surveys monitoring changes in the biometric features of spruce growing along the Czerwona Woda gave a unique opportunity to take measurements on the permanent research plots, not only by traditional methods but also by using latest technology. Installation of sensors on fenced surfaces (type A) allowed for the registration of changes in the crown layer (hemispheric cameras), in the thickness of trunks at the height of breast height (dendrometers) and in the root layer (minirhizotrons). Planned connection of the described sensors with the network enabling not only remote transfer of the measured parameters but also changing the recording time intervals and, for example, the depth of root layer scanning by minirhizotron cameras.

However, for a full picture of the spruce trees growing in the Czerwone Woda catchment or along other streams of the Park, it is necessary to extend the monitoring to additional surfaces. It is necessary to deploy them along the entire length of the streams, which will effectively illustrate the reactions of ecosystems, including changes in water conditions and other environmental factors. Therefore, in the autumn of 2018, another measurement cycle is planned. During this period, the material collected through dendrometers, hemispheric cameras and minirhizotrons from the entire observation year would already have been collected. This will allow an attempt to assess the impact of the hydrological state on the changes in the biomass of stands along the Red Water.

## Acknowledgements

The data and results presented in this work were created as a result of the research project 'Monitoring the impact of renaturisation and hydrological status on changes in the biomass of trees and stands' commissioned by the Stołowe Mountains National Park, as part of the program for financing certain activities carried out in the parks with forest funds in 2017.

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