

## ABOVEGROUND BIOMASS OF YOUNG SCOTS PINE ON DEGRADED SOIL IN THE CONTEXT OF USE FOR ENERGY PURPOSES<sup>1</sup>

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**Summary.** The study was concerned with the determination of the structure of aboveground biomass of 10-year old stands of Scots pine from the reclamation plantings at the Nitrogen Plant „Puławy” S.A., in the aspect of possibilities of use for energy purposes. The dry matter of trunks and branches with bark as well as needles was determined, and also their calorific value. The dry matter of trunks and branches was, on average, 20.5 tons per 1 ha, out of which nearly 70% was the mass of the trunks. The total aboveground biomass of the young pine stands after 10 years of growth attained an average of 32.3 tons per 1 ha, and its calorific value was 434 GJ · ha<sup>-1</sup>.

**Key words:** biomass energy, Scots pine, degraded soil

### INTRODUCTION

Problems with the acquisition of biomass for the needs of professional power generation create the necessity of supplementation of its deficit from a variety of sources. Setting up energy crop plantations on soils under agricultural use creates competition for agricultural production and the threat of infringement on the resources of soils predestined for food production. Therefore, it appears to be important to use idle lands, including post-industrial soils, for the production of biomass for energy purposes [Węgorek 2003, Pietrzykowski *et al.* 2009, Pietrzykowski and Socha 2010, 2011].

In 2002, the Nitrogen Plant „Puławy” S.A. started an afforestation program, mainly with Scots pine, on approximately 200 ha of idle lands in the direct vicinity of its industrial installations (in the so-called buffer zone).

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Observations of those tree stands conducted so far indicate a low level of cultivation culture and a high rate of mortality of the trees, the phenomenon of tree dying being unrelated with the natural process of separation of trees from the stands (not resulting from intra-population competition) [Węgorek *et al.* 2011].

The objective of the study was to determine the level of the resources and the structure of aboveground biomass of 10-year old stands of Scots pine (*Pinus sylvestris* L.) planted within the framework of the afforestation program on reclaimed areas at the Nitrogen Plant „Puławy” S.A. in the context of use for energy purposes.

#### MATERIAL AND METHOD

The study was conducted in 2011, in 10-year old pine stands, on three test plots with surface area of 420 m<sup>2</sup> each (29 × 14.5 m). According to Pranagal and Słowińska-Jurkiewicz [2002], the soils in the area are industrial soils and urbi-sols (in accordance with the PTG classification of Polish soils) developed from formations with the particle size distribution of loose sand. The soils are characterised by strongly disturbed chemism [Kowalkowski and Kopron 2002] due to long-term immission of nitrogen compounds, and additionally degraded through drainage related with intakes of ground waters [Siuta 1987, Kowalkowski *et al.* 1999].

On each test plot the heights (h) and diameters at breast height ( $d_{1,3}$ ) of all trees were measured, taking into account their morphological form, adopting the tree classification after Szymański *et al.* [1960]: correct build; deformed trees – two, three, twin, candelabra. From each test plot two trees were taken, with average dimensions  $d_{1,3}$  and h – 1 representative of trees with correct morphological form, and 1 representing deformed trees (on all test plots twos dominated among the deformed trees and the sample trees were chosen from among those). The sample trees (6 trees in total) were cut at the height of ca. 5 cm.

On the sample trees (after drying at temperature of 60°C) the following determinations were made: dry matter of trunks with bark, in thickness classes of > 1.0–5.0 cm and > 5.0–10.0 cm (sections with thickness up to 1.0 cm were included with branches); dry matter of branches with bark, in thickness classes of ≤ 1.0 cm and > 1.0–5.0 cm; dry matter of needles (all that were collected from a tree). For each thickness class of trunks and branches, and for the needles, the calorific value was determined with the calculation method (PN–EN 149018: 2010) on the basis of the heat of combustion assayed with the calorimetric method (PN–EN 149018: 2010) – at the laboratory of the Power Industry Research Institute „Energopomiar” in Gliwice.

The dry matter resources of the aboveground part of the tree stands were calculated, in Mg · ha<sup>-1</sup>, as well as its energy value – in GJ · ha<sup>-1</sup> (on the basis of the mass of the individual components of the aboveground biomass and the corresponding calorific values).

## RESULTS AND DISCUSSION

The number of trees on the test plots, converted to trees per 1 ha, was 4714, 4333 and 4024, the share of deformed trees being 27, 30 and 70%, respectively.

The dry matter of trunks and branches on the particular test plots, converted to values per 1 ha, was 16.9, 20.7 and 24.1 tons, respectively, the mean value being 20.5 tons (Fig. 1), nearly 70% of the total being the mass of trunks –  $14.3 \text{ Mg} \cdot \text{ha}^{-1}$  (range from 12.5 to 16.8  $\text{Mg} \cdot \text{ha}^{-1}$ ). Dry matter of trunks with thickness of  $> 5.0 \text{ cm}$  accounted for an average of 83% of the total mass of trunks.

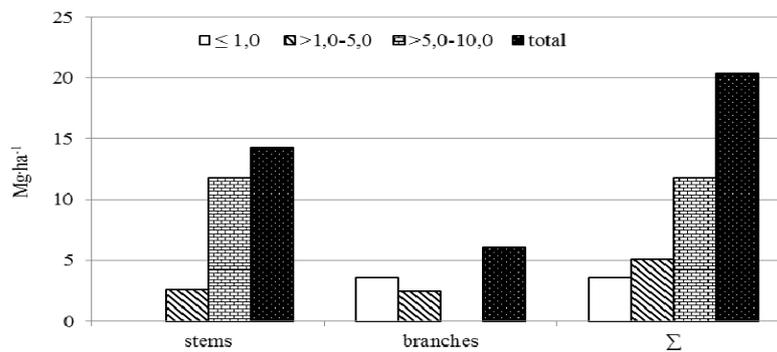


Fig. 1. Dry matter of trunks and branches per 1 ha, mean from 3 test plots

In the case of dry matter of branches, a higher share (60%) was that of branches with thickness of  $\leq 1.0 \text{ cm}$ . The average total mass of branches was 6.2 (range from 4.4 to 7.3) tons converted to values per 1 ha (Fig.1).

The dry matter of pine needles was, on average, 11.7 (range from 9.0 to 13.1)  $\text{Mg} \cdot \text{ha}^{-1}$  (Fig. 2).

The average aboveground biomass of 10-year old pine stands on the test plots was 32.3 tons d.m. when converted to values per 1 ha, trunks accounting for over 44% of the total, needles for 36%, and branches for 19% (Fig. 2).

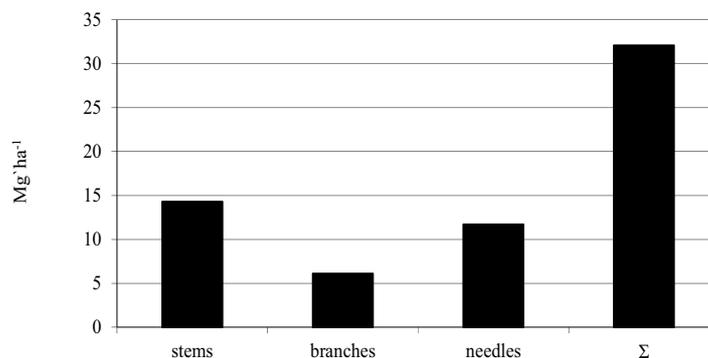


Fig. 2. Dry matter of aboveground parts of 10-year old pine stands

According to Pietrzykowski *et al.* [2009, 2010], the aboveground biomass of 12-year old pine growing on tertiary acidic sands (after neutralisation) of the external mine slope of KWB „Bełchatów” was  $8.12 \text{ Mg} \cdot \text{ha}^{-1}$ , of which  $6.43 \text{ Mg} \cdot \text{ha}^{-1}$  was the dry matter of wood and  $1.69 \text{ Mg} \cdot \text{ha}^{-1}$  was the dry matter of needles. As reported by Trampler *et al.* [1987], the potential productivity of dry coniferous forest wood biomass in Poland amounts to  $1.62 \text{ Mg} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$ . However, taking into account the fact that in young stands the annual increment of wood mass is considerably lower than the mean for the whole production cycle, the resources of the biomass in 10-year old stands will be notably below  $16.2 \text{ Mg} \cdot \text{ha}^{-1}$  (product of potential annual production and 10 years of growth of trees). According to the tables of resources and growth of tree stands developed by Szymkiewicz [2011], the stand volume of the large timber and the small timber of 20-year old pine stands on soils of quality class IV, under conditions of poor care, amounts to  $50 \text{ m}^3$ . Converting that to dry matter (with the assumption that the density of dry wood is  $470 \text{ kg} \cdot \text{m}^{-3}$ ), the stand volume would be  $23.5 \text{ Mg} \cdot \text{ha}^{-1}$ , and in the case of 10-year old stands – notably less than a half of that value.

Comparison of the above literature data with the results obtained in our study indicates that the young pine stands on the degraded sandy soils in the vicinity of the Nitrogen Plant „Puławy” S.A. are characterised by notable higher resources of aboveground biomass.

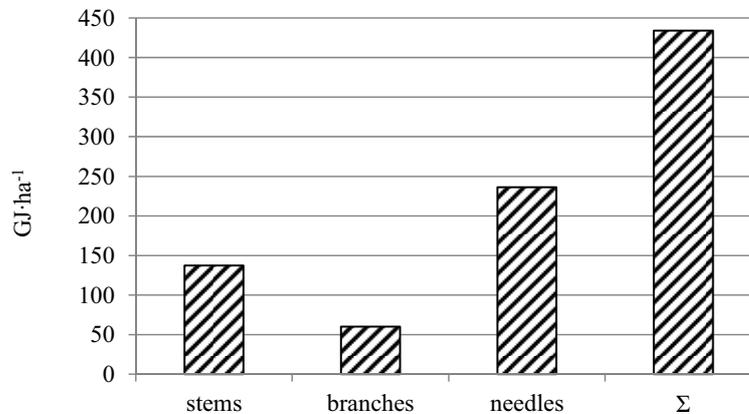


Fig. 3. Energy value ( $\text{GJ} \cdot \text{ha}^{-1}$ ) of aboveground „biomass yield” of 10-year old pine stands

The effects of biomass production under the conditions of our study do not appear as favourably in relation to the values obtained on willow plantations for energy purposes. Zajączkowski *et al.* [2001] report that the average annual yield of willow wood on a soil developed from light boulder loam was  $5.15\text{--}7.08 \text{ Mg} \cdot \text{ha}^{-1}$ . It needs to be emphasised, however, that this study was aimed at demonstrating the possibility of acquisition of energy plant material on idle lands totally unsuitable for agricultural production and with low suitability of forest production.

Determinations of the calorific value of the biomass revealed that the highest value of that parameter was obtained in the case of needles –  $20.2 \text{ MJ} \cdot \text{kg}^{-1}$ . In the case of the trunks in bark the calorific value in the trunk thickness classes of  $> 1.0\text{--}5.0$  and  $> 5.0\text{--}10.0$  cm was  $18.9$  and  $19.1 \text{ MJ} \cdot \text{kg}^{-1}$ , respectively, while in the case of branches –  $20.0 \text{ MJ} \cdot \text{kg}^{-1}$  ( $\leq 1.0$  cm) and  $19.6$  ( $> 1.0$  cm). The mean calorific value of pine wood from the degraded soils in the vicinity of the Nitrogen Plant (trunk and branches) was  $19.4 \text{ MJ} \cdot \text{kg}^{-1}$  – slightly higher than the value reported by Hartmann *et al.* [1999] –  $19.3 \text{ MJ} \cdot \text{kg}^{-1}$ , and distinctly higher than the value given by Komorowicz *et al.* [2009] –  $18.8 \text{ MJ} \cdot \text{kg}^{-1}$ .

The average energy value of the pine stands under study was  $433.9 \text{ GJ} \cdot \text{ha}^{-1}$  (Fig. 3). The shares of the trunks, branches and needles in the total „energy yield” were 32, 14 and 55%, respectively.

## CONCLUSIONS

1. Under the conditions of soils developed from loose sand, degraded as a result of nitrogen emissions and drainage, the 10-year old stands of Scots pine were characterised by high levels of biomass (32 tons of dry matter per 1 ha) with energy value of  $434 \text{ GJ} \cdot \text{ha}^{-1}$ .

2. Taking into account the hard to determine perspective of attaining the state of suitability of the area for forest production, and the current process of dying of the trees, it appears to be justified to use the afforestations (and subsequent renewals) for energy purposes in the shortened cycle of production.

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#### BIOMASA NADZIEMNA MŁODNIKÓW SOSNOWYCH NA GRUNTACH ZDEGRADOWANYCH W KONTEKŚCIE WYKORZYSTANIA NA CELE ENERGETYCZNE

**Streszczenie.** W pracy określono strukturę biomasy nadziemnej 10-letnich młodników sosnowych z zalesień rekultywacyjnych przy Zakładach Azotowych „Puławy” S.A. pod kątem możliwości wykorzystania energetycznego. Określono suchą masę pni i gałęzi w korze oraz igieł, a także ich wartość opałową. Sucha masa pni i gałęzi wyniosła średnio 20,5 ton w przeliczeniu na 1 ha, w tym prawie 70% to masa pni. Biomasa całkowita nadziemna młodników sosnowych po 10 latach wzrostu wyniosła średnio 32,3 ton na 1 ha, a jej wartość energetyczna 434 GJ·ha<sup>-1</sup>.

**Słowa kluczowe:** energia biomasy, sosna zwyczajna, grunty zdegradowane