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ANALYSING WOOD DENSITY AND BIOMASS: A CASE STUDY OF FOREST PLANTATIONS FROM MOLODOVA NOUA WASTE HEAPS, ROMANIA

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Abstract
The present paper emphasizes the possibility of using wood from the plantations installed on waste heaps by analysing the density of wood mass and establishing the biomass of species planted on the waste heaps from Moldova Noua. In order to determine wood biomass for the analysed species, wood samples were gathered from a specific sample area. As such, their volume and mass were established both before and after drying them in a stove at a temperature of 105 degrees Celsius for 24 hours. The plantations biomass was calculated by using wood density according to the work method previously described as well as the wood mass volume per hectare. The last element was determined after biometric measurements realized in 12 sample surfaces of 100 square meters each, arranged in four variants with three recursions. In the specific case of Moldova Noua waste heaps, the values obtained for wood density attest the high-quality wood of these plantations from the point of view of their density, in comparison with the wood from similar species grown under favourable vegetation conditions. Furthermore, analysing the productivity of plantations installed on the waste heaps from Moldova Noua, attest the framing of these plantations in an inferior production class from a productive point of view. The papers conclusions discuss the obtained results in the context of data from specialty literature concerning the productivity and wood density of forest plantations from the waste heaps located in Moldova Noua.

Keywords*: black locust, cooper ore, oleaster, tailing dumps, wood*

Introduction
Created as an outcome of material storage resulted from the flotation process, waste heaps, also known as cesspools, represent anthropic field surfaces in which the growth and development of vegetation is difficult due to sterile instability. This phenomenon is accentuated in Moldova Noua, Romania (Figure 1) by periods with winds characteristic to this area.
Dust pollution from Moldova Noua is a result of these surfaces together with the strong winds representative for this area. This type of pollution has displeasing effects on the other side of Danube, namely in Serbia. In the year 1988, this phenomenon has led to an international process won by the Yugoslavian Republic, in which Romania was obliged to stop the dust pollution from Moldova Noua. That juridical decision has contributed to motivating and accelerating the initiation of works.

As such, in the following period, the embankment and part of its neighbouring plateau were afforested, while the waste heaps plateau was grassed. The works were realized by Moldova Noua Forest District and S.C. Pajistea S.R.L. Moldova Noua based on a project elaborated by the Silvicultural Forest and Management Institute. The successful used species were: black locust (*Robinia pseudoacacia* L.), a species that usually does not vegetate well on very alkaline soils (Dinca 2017), oleaster (*Elaeagnus angustifolia* L.) and sea buckthorn (*Hippophae rhamnoides* L.). Besides its high content of vitamins and nutritive elements (Dinca et al 2018), this last species has the capacity to fix degraded fields (Constandache et al 2016).
These stabilization works enterprises on Moldova Noua waste heaps, with the help of vegetation, especially the forest one, have led nowadays to the presence of a phytogeographical complex that presents both perspectives for reintegrating these surfaces in the natural landscape, as well as results in this direction (Figure 1).

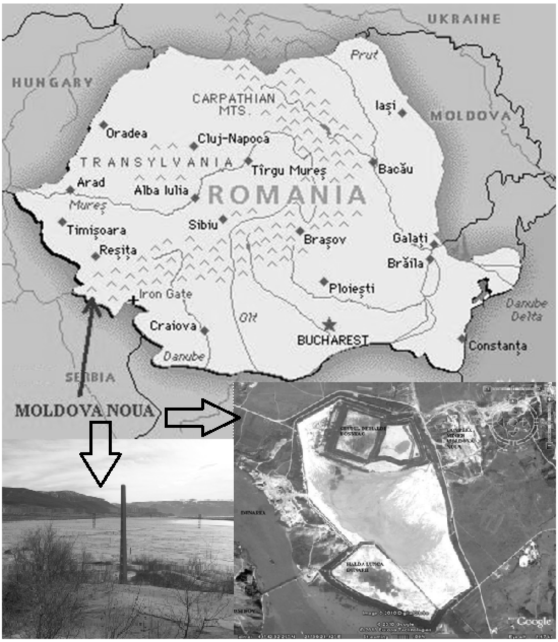

Figure 1. Waste heaps complex from Moldova Noua, Romania

The investigations detailed in the present paper have an important role in regard with the aging of current plantations, the eventuality of harvesting wood mass and the natural or artificial regeneration of surfaces that present waste heaps with the same forest species. Future capitalization of the wood grown in this area is also important for the present paper and demonstrates the possibility of using wood from the plantations installed on waste heaps by analysing the density of wood mass and establishing the biomass of species planted on the waste heaps from Moldova Noua.

Materials and Methods

In order to determine wood biomass for the analysed species, wood samples were gathered from a specific sample area. As such, increment cores from the 30 exemplars belonging to the selected species were extracted as follows: increment cores from 15 black locust exemplars and 15 oleaster exemplars. They were extracted from the plantations situated on three waste heaps (waste heaps number one and two from „Bosneag" group and waste heap number three from „Danube's Meadow"). Therefore, five locust increment cores and five oleaster increment cores were extracted from each waste heap. Their volume was then determined by total water immersion, by measuring the dislocated liquid volume.

After determining core volumes by using a 5 ml tube and the mass with the help of an electronic scale (both in humid and dry state), followed by stove drying at a temperature of 105°C for 24 hours, the apparent density was established for both dry and humid wood by using the following formulas:

$$\rho_{a_0} = \frac{m_0}{V_{a_0}} \quad (1)$$

where:

ρ_{a_0} is the apparent density for almost dry wood;

m_0 is the mass of totally dry core;

V_{a_0} is the volume of totally dry core.

$$\rho_{a_u} = \frac{m_u}{V_u} \quad (2)$$

where:

ρ_{a_u} is the apparent density od dry wood;

m_u is the core mass at a certain humidity of $0\% < u < 30\%$;

V_u is the core volume at the same *u* humidity.

The locust and oleaster wood biomass was determined by taking into consideration the above mentioned relationships, namely:

$$m = \rho \cdot V \quad (3)$$

The plantations biomass was calculated by using wood density according to the work method previously described, as well as the wood mass volume per hectare. The last element was determined after biometric measurements realized in 12 sample surfaces of 100 square meters each, arranged in four variants with three recursions: V_1 – plantations on the „Bosneag" group plateau, V_2 – plantations on the „Bosneag" group slope, V_3 – plantations on „Lunca Dunarii" waste heap plateau, V_4 – plantations on „Lunca Dunarii" waste heap slope. The disposal of repetitions from within the three variants was used by Blada, with another number of variants and repetitions. The current situation was adapted to the field arrangement of forest plantations situated on the waste heaps from Moldova Noua (Blada et al 2013).

A number of six trees were gathered from the plantations belonging to the three waste heaps, as follows: one locust tree and one oleaster from each waste heap. Their diameters were situated in the average diameter category (4-6 cm for locust and 2-4 cm for oleaster). The root was extracted for each of these trees in order to determine the total volume. The volume calculation for the extracted exemplars was realized through the xilometration and section method for the trees cone and only through xilometration for roots and branches.
In accordance with the methodology previously described, the determination of the plantations wood mass volume was realized based on the average trees volume. By extrapolating this value to the number of trees per hectare, the plantations volume per hectare was also obtained.

Results and Discussion

Locust and oleaster wood density

In the specific case of Moldova Noua waste heaps, the values obtained for wood density attest to the high-quality wood of these plantations from the point of view of their density, in comparison with the wood from similar species grown under favourable vegetation conditions.
The following tables render data regarding volumetric, gravimetric and densiometric characteristics for each sample, as well as the average density (expressed in kg/mc) both before (Table 1) as well as after the samples were dried in stove (Table 2).
An important fact to mention is that the samples average density is calculated based on the density of all samples and not based on the samples mass and total volume.

Table 1. The apparent locust and oleaster wood density for plantations situated on Moldova Noua waste heaps

Waste heap	Species	Total mass of samples (g)	Total volume of samples (ml)	Average density of samples (kg/mc)
1	Locust	4.23	5.10	833.222
	Oleaster	4.05	5.10	775.159
2	Locust	5.34	6.40	834.015
	Oleaster	4.2	5.30	777.436
3	Locust	5.04	5.70	883.074
	Oleaster	3.54	4.80	729.491
Apparent density of locust humid wood				850.104
Apparent density of oleaster humid wood				760.695

Table 2. The apparent density of completely dry locust and oleaster wood for plantations situated on Moldova Noua waste heaps

Waste heap	Species	Total mass of samples (g)	Total volume of samples (ml)	Average wood density (kg/mc)
1	Locust	3.29	4.70	701.30
	Oleaster	2.91	4.60	628.17
2	Locust	4.08	5.60	729.25
	Oleaster	2.58	4.40	584.70
3	Locust	3.67	4.80	764.75
	Oleaster	2.74	4.60	592.90
Apparent density of completely dry locust wood				731.77
Apparent density of completely dry oleaster wood				601.92

Therefore, the locust apparent wood density is of 850.1 kg/mc in a humid state and 731.8 kg/mc in a completely dry state. In the case of oleaster, density values of 760.7 kg/mc were obtained for humid wood and 601.9 kg/mc for completely dry wood.

Locust and oleaster biomass

Locust and oleaster biomass represents almost in totality the plantations wood mass volume. The biometrical characteristics of other species are much more inferior, having very low diameters and heights. As such, the biomass was calculated as a sum of locust wood biomass and oleaster wood biomass.

Table number 3 centralizes the results of calculating locust and oleaster biomass from Moldova Noua waste heaps.

Table 3. Locust and oleaster wood biomass from forest plantations installed on the waste heaps from Moldova Noua

Nr. crt.	Species	State	Density (kg/mc)	Volume (mc/ha)		Biomass (kg/ha)	
				Total	Without root	Total	Without root
1	Locust	Humid	850.104	39.9	31.2	33919.1	26523.2
		Absolutely dry	731.77	39.9	31.2	29197.6	22831.2
2	Oleaster	Humid	760.695	24.8	17.9	18865.2	13616.4
		Absolutely dry	601.92	24.8	17.9	14927.6	10774.4
Total humid wood biomass /ha						52784.4	40139.7
Total absolutely dry wood biomass /ha						44125.2	33605.6

The results obtained by us and rendered above where then compared with similar investigations as follow in the next paragraphs. A study concerning the locust biomass production realized in Slovakia in optimal vegetation conditions highlights certain similarities with the results obtained in the present paper. Bencat has studied the production of locust biomass in South Slovakia in three experimental surfaces with locust tree ages ranging from 8 and 27 to 49 (Bencat 1989). Interesting for us are the results obtained by the above-mentioned author in the experimental surface number 2, where the locust age at the research date was 27, with approximately 5 years older than the age of locusts from Moldova Noua waste heaps, at their harvesting date. The results obtained by Bencat in Slovakia reveal a density of 875.4 kg/mc for the humid wood and 566.8 kg/mc for the completely dry wood.

In Romania, experimental investigations concerning the physical properties of locust wood were realized by Porojan. She has studied locust wood harvested from two different geographical areas from Romania, North (Carei area) and South (Arges area). The locust wood from the North area presented a green wood humidity of 35.11 %, while the determined absolute density was of 664 kg/mc, meaning a humid wood density of 897.13 kg/mc. Similar values, without significant differences, were obtained for the locust wood from the South area, where the green wood humidity was of 36.42 %, the absolute density was 651 kg/mc, meaning a humid wood density of 888.1 kg/mc (Porojan 2009). Studies concerning oleaster, realized in Uzbekistan, have emphasized a density of the completely dry wood of 530 kg/mc (Khamzina et al 2006). However, the age of the studied oleaster was not mentioned.
In regard with the age and its influence on the woods density and caloric power, it is known that the low calorific values of young wood may be due to a low wood density, which corresponds to a soft wood texture of younger trees. The lower caloric values of softwood are explained by its lower content of hemi-cellulose in combination with higher content of lignin when compared with hardwood (Doat 1977).

Conclusions

For locusts with similar ages to the ones from Moldova Noua waste heap plantations but grown in Slovakia in other vegetation conditions than waste heaps or degraded fields, the humid wood density is of 875.4 kg/mc (Bencat 1989), a value close to the one determined by us in the present paper. The same author has determined a value of 567 kg/mc for the completely dry wood density, a value that is smaller than the one determined by us.
In our country, the values identified by Porojan for the absolute locust wood density are of 664 kg/mc (in North Romania) and 651 kg/mc (in South Romania), while the humid wood has density values of 897.13 kg/mc in North and 888 kg/mc in South. These values are similar with the ones obtained by us for humid wood (850 kg/mc) and completely dry wood (731 kg/mc)
In regard with the oleaster that vegetates on Moldova Noua waste heaps, the completely dry wood density is of 602 kg/mc, with over 70 kg/mc higher than the values specified in the specialty literature for this species, values determined by Lamers and Khamzinal in Kazakhstan (Lamers & Khamzina 2008).
By comparing these results with the ones obtained in the present paper, a similarity between humid wood densities is observed, as well as significant differences between absolutely dry wood densities. This fact is mostly due to growing differences and implicitly to the formation of a denser wood but with lower humidity in plantations situated on Moldova Noua waste heaps. The growths of locusts from Moldova Noua waste heaps are smaller, a fact that leads to the formation of a denser wood with a lower humidity content in comparison with the exemplars grown in optimal stational conditions.
The locust wood humidity registers a value of 16.17 % compared with the oleaster wood that reaches a humidity of 26.38 % with 19 % higher. These values were obtained by determining wood humidity for exemplars grown on Moldova Noua waste heaps, as a difference between wood densities determined after harvesting but in the same conditions for both species and the one obtained in a completely dry state. As such, we can recommend the wood of locusts grown on waste heaps as

having a higher absolute density and a better calorific power than the one of species grown in benevolent vegetation conditions. We consider that this species can we used successfully as fire wood in the case of exchanging or gradually replacing species from forest plantations situated on Moldova Noua waste heaps.

Furthermore, the oleaster wood grown on waste heaps is not inferior to the locust one in regard with its usage as fire wood. However, its arbustive appearance with a lower wood productivity makes it inferior to locust and does not recommend it as a sub stand for stimulating locust growths or as a prime intervention species for afforesting degraded fields. However, in order to be used as firewood, additional tests are required on the process of bioaccumulation of pollutants in plants and a characterization of combustion emissions, too.

As such, the energetic potential of arborescent or arbustive species is recognized and recommend them for planting on waste heaps in order to stabilize them (Dinca et al 2011, Dinca et al 2012).

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