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## **The problems of forest residuals utilization management in Poland**

### ***Introduction***

After the wood harvest process on the clear cut area has been finished, significant amounts of branches, needles, and tops of tree crowns are left on the clear-cut area. Those residuals when left produce serious inconvenience for the silvicultural operations such like soil preparation, and forest regeneration. Therefore, they have to be properly managed prior the onset of forest regeneration operations.

There are several technologies dealing with the managing the clear-cut forest areas. The least adequate is leaving the clear-cut terrain with all the residuals. Such an attempt is practiced in either very rich or very poor countries (e.g., USA, Russia- Siberia, Brazil, Malaysia) and it is usually the case of the huge single clear-cut areas. In the majority of situations, the residuals are managed following a number of methods. No single technology of utilizing the clear-cut residuals has been so far elaborated and applied in the Polish forestry practice. On the contrary: several variants are practiced, depending on the local circumstances. The most decisive practical criteria when choosing the proper method, is the efficiency and the cost of their application; important is also the environmental impact of the technology for the forest ecosystems.

### ***Goal and scope of paper***

The purpose of this paper was to present the review of the most popular systems of tree harvest residuals utilization as practiced in Poland's forestry. The most frequently used solutions are described together with the machinery, as well as the technologies of residual utilization. For some selected methods also labor demand and cost were calculated. The labor consumption was

calculated with the use of timekeeping technique and the cost per work hour was obtained followed a special calculating method. Additionally, tentative study has been done on the effect of different utilization methods of clear-cut residuals on the performance of the next forest generation culture, by the means of measurements of trees height.

### ***Results and their analysis***

Among the many methods of residuals utilization two techniques are especially important and worth of noticing:

- burning,
- grinding:
  - a) with use of a shredder; the crushed material is left in the forest,
  - b) with a chipper; the chipped material is either left in the forest or is transported and used outside the forest,
- bunching; the whole of the residuals are used for the energetic purposes).

In Poland, the first mentioned method used to be practiced most commonly. Its essence is in collecting piles of small sized wood residuals and burning them under control. Recently this method lost its importance and has been forbidden. The opinion is commonly accepted that it is environmentally detrimental because the burnt mineral particles are fast washed down the soil profile and can not be used by the young plants. Besides, during the process of combustion, several harmful compounds (like, e.g., carbon oxides) are being emitted to the atmosphere. Burning fires in the forest may produce, under some circumstances, increased uncontrolled fire risk. In some regions of the country, the relatively large size wood residuals are collected and taken from the forest by local inhabitants themselves.

More and more frequently, the site preparation works are conducted with use of specially designed machines. It is possible to crush the harvest residuals and leave them in the forest so as they could provide the reservoir of food substances for the newly established forest culture; another solution is to purpose the chipped wood residuals for the energetic aims, or industrial uses. Of course, wood chips may well be left in the forest but in such a case they would have to be dispersed all over the clear-cut area. To leave the crushed wood on the clear-cut area may result in an increased risk injury risk of the young forest cultures due to the pine weevil. Some

Forest Districts practice the year-long abandonment of the clear-cut area, just in order to minimize the danger. This is important problem worth of a separate discussion.

Nowadays, many firms produce the equipment for wood comminution. Basically, those are machines supplied with high-speed rotating cutting elements. In Poland, the below listed wood crushing machines are, among others, frequently used: the rotating crusher MF-160, Seppi, AHWI, Meri Crusher, and many others. Similarly, many chipping machine types are applied in Polish forests (e.g., Farmi, Bandit, Bruks, Skorpion etc.). The process of harvest residuals fragmentation (crushing) is possible to conduct without site preparation. The crusher machine moves across the entire clear-cut area, crushing the branches and crown tops wherever they are left. An alternative solution is to form (either manually or mechanically) residual wood piles or rollers. This operation (collecting and transporting the branches, the cut undergrowth and the left crown tops) may be executed with use of different type rake machines. Those are in the most cases, items aggregated with either special tractors or farmers' tractors. Sometimes, to produce rollers, bulldozers are used.

The biomass left in the forest is a potential energy source. A large progress in utilizing of the biomass has been recently observed in the Scandinavian countries, and especially so in Finland and Sweden; in these countries detailed technological solutions have been elaborated of the wood harvest residuals utilization. Special machines bunch the small sized round wood residuals in parcels about 3 m long each, 60-80 cm of diameter and 300 – 700kg weight. While combusting such a bunch, about 1 MWh energy is being produced. The efficiency of the machine varies, depending on the individual operator's skills and the volume of material, from 20 to 30 bundles per hour. The bundles are transported by forwarders to the to the main road, and then are loaded into vehicle sets are transported to the power station, where they are burned. The compressed bundles are subject to chipping with use of special chipper machines before they are combusted in the power plants. The bunching machines are constructed based on the standard forwarder are produced, e.g., by Rottne ( Wood Pac 800) and Timberjack (Fiberpac FB 370).

Particular technological solutions of wood harvest residuals utilization are characterized by specific values of technological-economical parameters, and by diversified impact onto the forest environment. The efficiency of particular methods is shown in Fig.1. The absolutely most time consuming operation is the manual forming of piles and their burning. The least time consuming – and thus: the most efficient, is the use of the mobile SEPPi crusher that freely

moves all over the clear-cut area. The earlier formation of rollers makes the efficiency of the machine lower. This is a consequence of the necessity to the many passes of the machine at low speed and the need to many reverses of the set: the machine and the tractor, in order to reach the satisfying degree of grinding of the woody material. Similar level efficiency was stated when examining the wood residual chipping with use of Bandit 200+ chipper.

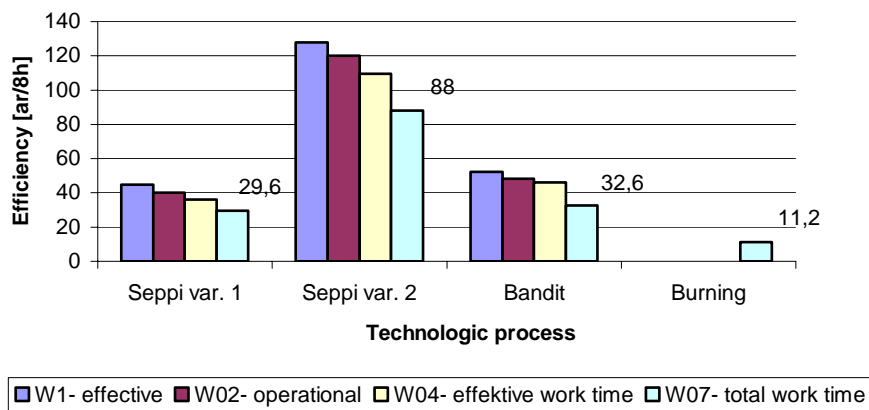


Fig 1. Comparison of efficiency of the analyzed processes

variant 1 – fragmentation of residuals formed in rollers

variant 2 – fragmentation of residuals left on the entire area of the clear-cut

The simulated (expected) cost of machine labor (table 1) suggests that the cheapest solution would be residual burning on ground. The second cheapest technology is that with the use of „Seppi” crusher. While calculating the cost there was included the cost of purchase of a tractor and the machine. Noteworthy is the cost increase when a 4 hour work day has been applied. It is therefore very important to properly organize the work, so that the effective utilization of the equipment be possibly highest. Considering the labor consumption alone, we come to the conclusion that the cost of 1 ha clear-cut area preparation for the necessary silvicultural operations is minimum after the method of residual controlled burning on ground has been applied (approximately 610 PLN/ha). In the case of the „Seppi” crusher use one has to spend about 938 PLN/ha. All the remaining methods considered are definitely more expensive.

Table 1. The cost of particular technological processes. [PLN/ha]

PROCESS		COST [8h/24h]	COST [4h/24h]
BURNING		610	610
SEMPI	Variant 1	2783	4498
	Variant 2	938	1516
BANDIT		3388	5036

In order to determine the effect of different treatments (managing of the wood harvest residuals) on the next generation of forest stand, the height of young planted trees was measured in Sychowo Forest District. The measurement results are presented in Table 2.

Table 2. The average tree height in particular research plots.

	plot 1	plot 2	plot 3	plot 4
Mean [ $\mu$ ] (cm)	22.6	20.6	40.5	40.9
Variance [ $s^2$ ]	54.2	51.9	168.7	225.3
Standard deviation [ $s$ ] (cm)	7.4	7.2	13.0	15.0
Variation coefficient [ $W$ ] (%)	32.6	34.9	32.1	36.7

plot 1 – this site was prepared before planting the new culture through chipping of the harvest residuals and dispersing them over the clear-cut area. The forest regeneration applied was planting Scots pine 1/0 seedlings.

plot 2 – the wood residuals were burned in this site and the ash was dispersed over the area. Planted with 1/0 seedlings.

plot 3 – the residuals were treated as above but the area was planted with 2/0 seedlings.

plot 4 – the residuals were removed from the area. 2/0 seedlings were used for forest artificial regeneration.

It is to conclude that the young planted forest was relatively worst in those plots (nr 2 and 3) where wood residuals were burned; moreover, the weeds were heaviest in the plots and they have started to negatively influence the trees. Besides, in those places with abundant amounts of ash the vitality of pine culture was worsened. In plot 4 however (with remover residuals) the weeding was at the level similar to that of plots 2 and 3; in this plot no decreased tree vitality was however observed unlike plots 2 and 3.

### *Summary*

The relatively highest negative consequences were observed after the cheapest method of burning the residuals on ground had been applied. Rather advantageous are the treatments with grinding the residuals with use of special tractor-suspended crushers. Especially promising seems the “Seppi SF 200” crusher. The work quality of the machine, and the resulting time consumption and cost are maintained at a reasonable level.

A serious drawback of all the discussed methods of clear-cut waste wood utilization is the necessity of multiple crossing the clear-cut area by the tractors with the aggregated with them crushing/chipping devices. As a result, the rotating working shaft with beaters mix the upper soil horizons and eliminates partially some organisms important in the life of the soil. Considering the fact, it seems that the proper solution would be to chip the residuals and leave them on the clear-cut area. The accepting of this solution would mean the very much time-consuming alternative and thus – expensive. The cost might be reduced by the use of the following modification: the residuals are raked and rollers are formed, and then a mobile chipper moves parallel to the roller, dispersing the chips over the clear-cut area directly from the chute. No solutions have been so far practiced in Poland connected with the bunching of small sized wood residuals and to be used for the energetic purposes exclusively. It seems however that also in Poland the interest in the renewable energy sources will increase in the near future.