Abstract: Investigations on logging process of wind damaged trees with the internal combustion chain saw. The work aimed at determination of the time share of particular technological operations in the process of wood logging of various types of damaged trees. The investigations were carried out during redressing of the hurricane effects in Forest Inspectorate Osie RDLP Toruń in June 2007. It was found that number of operations executed on a tree did not directly affect the logging time. The longest logging time was found for standing inclined trees and windfallen trees (on the average 232 sec. and 181 sec., respectively). Branching was most time-consuming operation and averaged to 57.5% of logging time for all investigated types of trees. It was found that technological down times resulting from specific after-calamity conditions could prolong even several times the logging time of a given tree.

Key words: windfall, logging, operational time balance.

INTRODUCTION

Logging on natural calamity sites is regarded as one of most dangerous forest operations. It is mainly connected to variability of situations resulted from a strong wind impact or e.g. fire; this calls for individual approach of the chain saw operator (Suwala 2004; Muszyński 1999). The broken or partly burnt root systems of trees cause their self-acting falling of still standing trees under even weak wind or the part of crown of adjacent tree during its falling. Strong and difficult to determine internal stress of heaped trees, especially on wind-damaged sites, can cause hitting of saw operator with a tree during unskillful felling, branching or cross-cutting; this often results in a serious accident leading to continuous disablement for work or death (Brzózko 2009).

Application of mechanical logging considerably improves the work safety. The operator of logging machine is protected by a cab, and he can reduce an internal stress in wood by its stretching or shifting with the use of machine. He is usually remote from the place of processing, therefore, even throwing away of strained tree can damage e.g. the working head, but the operator is protected from direct contact with the tree being processed.

However, mechanical logging can not be always applied. If there is lack of appropriate machine or tree damages are small, e.g. in the form of small-area pockets, logging of after-calamity wood in Poland is most often executed with the use of internal combustion chain saws.
The work aimed at recognition of the time balance of saw operator’s work during wood logging of damaged trees on after-calamity area. It would allow for further comparison to the effects of saw operators’ work under felling and pre-felling conditions on undamaged sites. It may enable to determine the effect of difficult (after-calamity) conditions on the logging time prolongation when compared to normal conditions.

MATERIAL AND METHODS

The investigations were carried out on the site of Forest Inspectorate Osie RDLP Toruń in the forest district Zajęczy Kąt, where on 11th May 2007 a several-minute hurricane occurred; it resulted in devastation of 100-year old forest stand in 342d compartment. The estimated area for felling amounted to about 1 ha, while the total volume of trees to be removed was equal to about 200 m³.

The investigations consisted in observations and recording of logging process (with no interference in its realization) with the use of a digital camera.

A five-person team of Forest Service Establishment from Forest Inspectorate Osie was involved in raw timber logging. All workers were very experienced professionally (about 15-20 years of forest employment). The wood was harvested in the longest possible segments. The sawman with his assistant were felling, throwing down, branching and cutting off the tree-top and not useful tops. The task of skidding man was skidding of usable segments with the use of tractor with a yarder to the logging road, where segments were processed and piled by the second sawman with his assistant.

The working team was equipped with:
- two internal combustion chain saws Husqvarna 357XP,
- agricultural tractor Ursus C-330 with log stacker, yarder and catching ropes,
- two axes, plastic wedges, lever – cant hook,
- five safety helmets (for each worker); the sawmen were additionally equipped with: trousers with anti-cutting insert, anti-vibration gloves and eye and hearing protectors.

The work of sawman and his assistant was observed on the after-calamity site during logging. The assistant’s task was to remove branches that disturbed in the sawman’s work during branching, and to put in and to strike of wedges during felling and – if necessary – during cross-cutting. Additionally, then sawman often consulted his assistant with respect to making kerfs during felling and cross-cutting.

The damaged trees were differentiated as follows:
- standing trees inclined (designated as type 1),
- high and low standing trees with broken off part of tree stem (type 2),
- windfallen trees (type 3),
- gate-type broken trees (type 4),
- lying tops broken off from standing trees that supplemented type 2 (type 5).
The effect of main parameters of the tree and of the chain saw on timber harvesting time is well known and described in references (Kozłowski 2003; Maciak 2006; Wójcik 2007). One of most important parameters is diameter of harvested trees. Since measuring of damaged trees’ diameters prior to harvesting was impossible with respect to safety, this factor was estimated on the basis of comparison between the length of chain saw guide used by sawman (45 cm), while particular trees were included in the following ranges: 20–30, 30–40, 40–50, 50–60 and 60–70 cm. No trees of bigger or lower diameters were found in the investigated sample.

In the process of timber harvesting executed by the sawman and his assistant the following operation were distinguished:
1. Felling operation consisted of:
   1.1. Preparation of place,
   1.2. Execution of undercutting kerf,
   1.3. Inclining of tree (beating of wedges),
   1.4. Execution of cutting kerf,
   1.5. Additional operations.
2. Branching operation consisted of:
   2.1. Cutting off branches and knots,
   2.2. Pulling off branches,
   2.3. Additional operations.
3. Cross-cutting operation consisted of:
   3.1. Preparation of place (pulling off branches, pulling off tree stem),
   3.2. Cutting off blocks,
   3.3. Additional operations.

Depending on type of tree damage the logging process could consist of additional operations occurring during execution of distinguished operations, including e.g. removing of suspended tree, releasing of jammed guide (beating of wedges) or cutting off the supported top. Of course, some operations presented in points 1–3 might not be included.

RESULTS OF INVESTIGATIONS AND THEIR ANALYSIS

Figure 1 presents the time balance of particular technological operations in timber harvesting as a result of observations of tree damaged by their inclination (type 1) on the investigated wind-fallen site. In this case the preparation of working place was not time-consuming; in three cases it amounted to 10, 11 and 13 seconds, while un the remaining cases it was needless.

This type of damage is characterized by a forced direction of falling tree resulted from its inclination. Its consequences could be observed in branching. Although average branching time for such type of tree amounted to 120 sec., in the case of the last tree it amounted to 412 sec. This increase was caused by the tree placing among thick bushes and previously cut branches, forced by direction of falling, that made branching longer and more difficult. It was not only difficulty connected with tree falling direction, which can be slightly corrected by an experienced sawman, but sometimes suspension of tree can not be avoided. It occurred in three cases, where pulling off the suspended trees amounted to 115, 163 and 170 sec., affecting an average time of timber harvesting of these trees.

Figure 2 presents time balance for particular operations of technological process of timber harvesting for standing
trees with broken off part of tree stem (type 2). A basic difficulty here was determination of direction of falling. In trees without crowns, direction of the tree’s gravity centre leaning is far more difficult to predict. It was proved by results of investigations. The average time of preparation amounted to 15 sec. and was highest among the investigated types of trees, since the sawman deter-
mined direction of falling. Unlike type 1, the preparation took a significant part of total harvesting time. The difficulties in determination of falling direction affect also the method of logging. In felling of trees with this type damage the woodcutter was leaving slightly bigger hinge to enable the tree movement in other direction than assumed. Additionally, all trees (except one) were fallen with the use of wedges (for safety reasons).

Branching was executed in the three cases out of seven, but was the longest operation. The lack of branching in the remaining cases resulted from the lack of branches and knots on sides of tree. It occurred always in low-broken trees and in most cases in medium-broken trees.

Figure 3 presents time balance for particular operations of technological process of timber harvesting for wind-fallen trees (type 3). Timber harvesting from trees of this type seems apparently simple; trees are already blown over so there is no need for cutting kerfs and falling. However, there were observed many specific situations that do not occur under conditions of undamaged stands or occur occasionally; they affected particular operation times of the entire logging process. These factors were found mainly in this group of damaged trees, e.g. technological breaks occurred in six cases out of twenty one and consisted in pulling off trees out of piles and in releasing of jammed guide. One tree was particularly difficult; all specific times were here longer than that for other trees. It was caused by large number of branches and difficult access to the tree stem. To branch this tree fully, a skidding tractor’s yarder had to be used.

![Figure 3](image_url)

**FIGURE 3.** Time balance for particular operations of technological process of timber harvesting for windfallen trees (type 3)
to pull off other trees from an after-hurricane pile. It was complicated operation, since trees were additional twisted which called for appropriate operational sequence. In this case the cross-cutting time exceeded 440 sec. (over 7 minutes). The logging process was difficult due to stresses, big stem diameter and the butt broken along its fibres. The long time resulted also from necessity to cut off the rootstock and later the broken butt from the stem. In total pulling off the jammed guide lasted over 300 sec (over 5 minutes). For comparison, the average cross-cutting time for trees of this time amounted to 51 seconds.

Figure 4 presents time balance of particular technological operations of timber harvesting from gate-type broken trees (type 4). This type of damage is one of most difficult in logging on wind-damaged site. The sawman had to be extremely careful since a broken top could come off the stem, creating a serious threat to health or even life of him and his assistant. Proper identification of stresses in the ground-supported part and the butt part of stem can be difficult for inexperienced sawmen. The top by its weight inclines the butt part slightly, while big stresses are created inside the tree’s fibres. Another characteristic feature of wind broken trees is a large number of required operations. Although the butt part can be regarded as the entire tree, one should consider also additional operations as e.g. cutting off the supported top or additional places of cross-cutting – in the place of stem breaking.

Preparation for felling of gate-type broken trees did not take much time, although it was executed more carefully than for other trees with respect to hanging top – on the average it lasted 11 sec. In cutting off the supported top the obtained results were more varied: the
shortest time amounted to 9 sec, the longest 35 sec. Times of kerf execution: undercutting, cutting and branching were similar to other types of damaged trees.

Figure 5 presents time for branching and cross-cutting of tops broken off the stem and laid on the ground (type 5). Very short cross-cutting time and significantly longer branching time are characteristic for trees of this type. The loggers do not like this type of damage since it calls for a big sawman’s effort in branching of numerous branches and timber harvesting productivity is small due to usually small diameter of assortments.

Figure 6 presents the specific average time balance of operations depending on type of harvested wood damage.

The least average time of timber harvesting was found for standing trees with broken off crown. It may be strange, but other trees requiring less technological operations were harvested slower. It can be explained with the fact that felling of trees with damage of this type are similar to typical undamaged trees. Therefore, in spite of fairly big number of operations on a single tree, the sawman’s work was efficient and quick. Additionally, a small number of branches significantly shortened the time of branching.

Average time of timber harvesting from gate-type broken trees was by several seconds longer than that for standing trees without tops. It might be caused by small dimensions of gate-type broken trees when compared to other trees as well as big experience and professionalism of the sawman. Another reason could be the usual smaller density of broken trees, enabling much freedom in the chain saw handling.
The laid tops broken off the stem, in spite of appearances, were not in the group of quickest harvesting. They did not require many various operations, but the work was laborious and less effective. Branching itself lasted longer than average time of total harvesting of fallen and gate-type broken trees. The laid tops were often placed in dense bushes of shrub layer or were entangled with other branches.

The windfallen trees were processed on the average by about 200 sec. and so long time could be caused by dimensions of trees. While in previous cases the sawman processed only the part of standing tree (butt or top), he had hare to branch the whole length of tree and this time took half of total time. The cross-cutting of such trees was also not easy. Trees laid often in piles, one on another, that caused strong stresses; this always slows down the operations due to necessity of their minimization. Unskillful or careless cutting off rootstock may cause unintentional kickback of stem or crushing with the rootstock returning to ground or laid in direction of the stem. Various wood stresses call for consultations on application and utilization of tractor yarder.

The inclined trees often occur under normal felling conditions, however, inclinations of windfallen trees are bigger. While at small inclination it is possible to correct direction of falling, at strong...
inclination it is limited. Therefore, the feller practically does not affect the direction of falling that is influenced by the wind direction inclining the tree. This complicates branching; in this case it took half of operational time on a tree. Rest of operations did not much differ from average values obtained for other tree damage.

In total about 32 m³ (46 trees) were harvested during investigations. Operational productivity amounted to about 4 m³/h. This value should be regarded as very high. However, it should be noted the work was done by a very experienced team, and in order to increase the maximal productivity not all safety requirements were observed (e.g. the sawman abandoned preparation of working place for felling). Therefore, comparison of the obtained results to that obtained under normal conditions can not be taken as a basis for general conclusions. The investigations should be then continued on the sites of other type.

CONCLUSIONS
1. Number of operations executed on a tree does not influence directly the rate of logging. Timber harvesting from gate-type broken trees lasted on the average about 90 s with five operations executed, harvesting from the laid tops about 110 sec. with two operations.
2. The most time-consuming operation was branching; it took 57.5% of total time on the average for all types of trees. It is consistent with results of Wójcik (2007) for experienced sawmen harvesting timber with clear felling area by long log system, where branching time amounted to 57% of total harvesting time.
3. The investigated team most harvested timber most quickly from broken trees (on the average 83 sec.) and gate type broken trees (93 sec.), then from laid tops (113 sec.), windfallen trees (181 sec.) and inclined trees (232 sec.).
4. In inclined trees and windfallen trees of shortest harvesting time, there occurred technological breaks more often than for other damage types; it was caused by factors characteristic for after-calamity conditions (e.g. for inclined trees the average time of pulling off the suspended tree amounted to 64 sec. while for windfallen trees the average time of releasing the jammed guide amounted to 25.2 sec.).
5. Some operations executed during work on windbreak site are more difficult when compared to undamaged conditions. It influenced the range of time, e.g. branching amounted to 12 to 412 sec.
6. The operational productivity achieved by the team was high as for after-calamity conditions, but with a sacrifice of safety due to excessive hurry.
7. Diameter of trees of the investigated sample did not significantly influenced the harvesting time. This is opposite to results obtained by other
authors for undamaged felling stands (Wójcik 2007). However, one can not conclude that it is caused by after-calamity nature of site, since it may result from small sample size recorded for particular types of damage. Therefore, it can not be generalized. Further investigations are needed to confirm it.

REFERENCES


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