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Exposure to noise in wood chipping operations under the conditions of agro-forestry

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ABSTRACT

An increasing number of agricultural contractors are getting into industrial wood chipping, following the rapid expansion of fiber farms on ex-arable land. Wood chippers are noisy machines and agricultural contractors tend to work long hours, which raises the question about their exposure to noise. The objective of the study was to quantify noise exposure for this occupational group. The Authors selected a representative operation and monitored noise exposure for five full working days, covering the main job types typically encountered in agro-forestry. Noise exposure was highest during chipping time, with 81.8 dB(A). The main source of noise was the powerful diesel engine, followed by the chipper drum: they generated the highest noise levels in the 100–200 Hz and the 20–50 Hz frequency ranges, respectively. Daily noise exposure did not exceed the 80 dB(A) lower action value, and it was similar to the exposure of other workers operating industrial in-wood chippers. However, future optimization measures may lead to increasing the proportion of total time when the machine is under full load, and it generates the highest noise levels. Modeling exposure as a function of efficiency showed that exposure levels may exceed the lower action values, once utilization will increase above 64%. This is a realistic target, which may be achieved in the near future. Fortunately, the problem will materialize only with some specific operation types, which represent a minor component in the wood basket of agro-forestry chipping companies.

1. Introduction

The European Union has set ambitious new targets for biomass use, with the main purpose of mitigating climate change and the harsh global competition for fossil fuels (Berndes et al., 2003). That has generated an increasing demand for renewable fuels, and especially wood-based feedstock (Krausmann et al., 2008).

In Europe, forests are still the main source of wood fiber, but they are largely underutilized (Ericsson and Nilsson, 2006). Remote location, difficult terrain and stringent environmental constraints make forest harvesting especially difficult, which results in the high supply cost of forest biomass (Spinelli et al., 2014). Agro-forestry is often considered as a good alternative for cost-effective wood fuel production (Hoogwijk et al., 2003), and it is supported by the European Union with attractive grant schemes, in an attempt to increase biomass availability and to promote rural development at the same time (Stupak et al., 2007).

As a consequence, specific machines have been developed for harvesting agro-forestry biomass, which are different from both dedicated forest equipment and conventional agricultural machinery (Spinelli and Magagnotti, 2011). Among them, one can identify a whole family of large scale industrial chippers, obtained from the combination of a forestry chipper and a large farmland carrier, such as a forager or a combine harvester (Manzone and Spinelli, 2013). These machines are likely to become very popular, following the projected expansion of agro-forestry in the next coming years (De Wit and Faaij, 2010). That would represent a momentous change for agricultural work profiles, because until now full-time agricultural machine contractors have always worked with feedstocks other than wood, while wood has been normally handled by part-time self-employed farmers using non-industrial technologies. Due to their peculiar characteristics, agro-forestry wood chipping machines and operations may present new and specific challenges, including specific occupational hazard. In particular, most of these machines are designed in such a way that the operator cab is very near to the chipper drum, which is not

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reflected in conventional forestry chippers. In that respect, these machines are somewhat similar to a combine harvester, with the main difference being that they process wood instead of softer grass or cereal (Spinelli et al., 2009). Furthermore, agro-forestry operations are generally characterized by a lower incidence of delays compared to conventional forest operations (Spinelli and Visser, 2008), which results in higher productivity but also in a sustained exposure to a number of different stressors, generally absent during downtime.

Exposure to noise is an important and preventable cause of hearing loss (Dobie, 2008), currently imposing a heavy burden on society at a global level (Nelson et al., 2005). Noise-induced hearing loss can be caused by short exposures to extremely high sound levels or by repeated exposures to moderate levels. The main effect of high-intensity sound is manifested in the form of temporary or permanent loss of sensitivity and acuity (Dixon, 1998). The European Union has set clearly defined exposure limit values on daily noise level and peak sound pressure. According to Directive 2003/10/EC, daily exposure should not exceed 87 dB(A), or 140 dB(C) under any circumstances. The same directive also sets the upper exposure action value at 85 dB(A) or 137 dB(C), and the lower exposure action value at 80 dB(A) or 135 dB(C).

When working with wood supply, occupational health researchers have generally targeted chain saw operators (Axelsson, 1998; Toppila et al., 2005), who are exposed to the highest noise levels and figure prominently in epidemiological studies (Miyakita et al., 1987; Pyykkö et al., 1981). Concerns have also been expressed for the drivers of traditional wood extraction harvesting equipment, such as harvesters, fowarders and skidders (Gerasimov and Sokolov, 2014). Use of harvesting equipment leads to hearing threshold shifts, with maximum at 4000 Hz (Fonseca et al., 2015). Few studies have addressed the exposure of wood chipper operators, partly due to the very recent interest for this specific practice (Magagnotti et al., 2014). The few available studies indicate that exposure varies with machine type (Brueck, 2008; Rottensteiner et al., 2013) and operator work station (Suchomel et al., 2011). However, these studies have been conducted on conventional in-wood chippers, not on the new models developed for agro-forestry.

Therefore, the goals of this study were: 1) to determine operator exposure to noise during work with a dedicated-agro-forestry chipper, for a range of typical work conditions, such as riparian stands, parks and short rotation forestry (SRF) and 2) to model operator exposure as a function of operational efficiency.

2. Materials and methods

The study was conducted on the Albach Silvator 2000 agro-forestry chipper, a new machine recently developed in Germany for industrial chipping operations (Fig. 1). The machine consists of a powerful drum chipper installed on the same heavy carrier used for root beet harvesting. Use of such carrier offers greater all-round mobility, compared to conventional forwarder-mounted and truck-mounted in-woods chippers (Spinelli and Magagnotti, 2010). The machine is equipped with a 10-m reach forestry loader for independent chipper feeding, and is powered by a 450-kW diesel engine installed over the rear axle. Total machine weight is 32,000 kg. The chipper drum has a diameter of 1 m, and a width of 1.2 m. It carries 12 knives distributed in a staggered pattern, and it turns at 500 revolutions min^{-1}.

The specimen under observation had been purchased in 2013 by an Italian farming contractor, who had used it for 800 h before the study. The machine was in very good conditions, and the owner-operator performed all scheduled maintenance according to the manufacturer instructions.

For the purpose of the study, the machine worked for five full days on three different sites, representative of the different work conditions typical of agro-forestry (Table 1). All sites were located in Northern Italy, where agro-forestry and short-rotation forestry are especially popular (Manzone et al., 2009). Measurements were conducted in February 2013 and lasted a total of 18.6 h.

Time study techniques were used to split daily work into different activities (Table 2), so that noise exposure could be tied to individual phases of machine operation and modeled as a function of work day structure (Magagnotti et al., 2013a). The time studies were performed using a Trimble Recon handheld computer, running the dedicated Laubrass UMT Plus© time studies software. The limitations of the handheld are few, because it is small and enables easy operation even in bad weather. Data loss is very unlikely to occur, as the data is saved even if the battery fails.

Exposure to noise was measured with a Brüel & Kjær 2250 sound meter, equipped with a 4189 model microphone. This was mounted inside the cab, on the left side of the windshield at the same level as the operator's head. The exponential time weighting was set to fast and the logging interval to 1 s. Therefore, every second the instrument logged the following records: equivalent continuous A-weighted sound pressure level (LAeq); maximum value of the C-weighted instantaneous sound pressure (LCpeak); full sound frequency spectrum in 1/3 octave bands, without weighting (LZeq). The class 1 sound meter carried out the measurements with the highest accuracy, recording one-third-octave band frequency spectra, which was not possible for standard noise dose meters.

Noise was evaluated according to European directive 2003/10/EC and international standards ISO 9612:2009 and ISO 11201:2010. The "full-day measurement" option was chosen among the three alternative strategies proposed by ISO 9612:2009. Therefore, the daily exposure level ($L_{EX,8\ h}$) was calculated with equation (1).

Fig. 1. The Albach Silvator 2000 agro-forestry chipper used in the study.

Table 1
Site description.

Site	n	1	2	3
Municipality		Imola	Padova	Piacenza
UTM Coordinates	Northing	44N 35′ 87.1″	45N 36′ 32.4″	45N 05′ 35.9″
	Easting	11E 71′ 27.2″	11E 90′ 71.2″	9E 87′ 21.1″
Stand	type	Riparian stand	Park	SRF plantation
Species	code	W, A, P	W, P, M	P
Operation	type	Cleaning	Removal	Maturity cut
Chipped parts	type	Residues	Whole trees	Residues
Study duration	h	9.8	8.4	8.3
Productivity	$m^3\ h^{-1}$	33.1	53.2	50.8

Notes: W = Willow (salix sp.); A = Alder (Alnus glutinosa L.); P = Poplar (Populus sp.); M = Mulberry.
(Morus nigra L.); m^3 = m^3 loose chips.