Advantage

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Contents

Understanding the nominal ground pressure of forestry equipment

Abstract

Nominal ground pressure is an important criterion used to predict the effects of a machine's weight and configuration on forest soils during harvesting activities. This report discusses the concept of nominal ground pressure, how it applies to various common machine types, and the impacts of various machine configuration options.

Keywords

Nominal ground pressure, Soil disturbance, PASCAL software.

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Introduction

Harvesting and silvicultural activities may create soil disturbance in the form of compaction and/or rutting, which can lead to soil erosion and nutrient loss. Concerns about the short- and long-term effects of these operations on the health of forest soil, on water quality, and on tree growth arise whenever these disturbances become sufficiently severe or extensive to damage the soil and site or to result in off-site movement of soil.

The potential for soil disturbance by forest operations can be reduced by proper planning and by using best operating practices. For example, wet areas can be harvested in the winter, when the ground is frozen, and brush mats can be used to cover extraction trails. FPInnovations has produced several publications that describe operating techniques capable of reducing the impact on forest soils. (See the References section for details.)

The impact of forestry operations on forest soils is also influenced by the ground pressure created by the equipment. This pressure represents the amount of force the machine exerts on the soil, and plays a key role in determining the risk of soil compaction and rutting. Understanding the importance of nominal ground pressure and knowing their values for a variety of machine types can aid in the selection of a machine for a given operation or soil condition and contributes to the ability of forest operations to respect environmental management system requirements as well as government soil and vegetation protection regulations.

FPInnovations has produced a tool (the PASCAL spreadsheet) that managers can use to predict the nominal ground pressures exerted by their equipment. This report describes this software, and focuses on harvesting machines, their configurations, and the impacts of tire size and tracks on nominal ground pressure.

What is nominal ground pressure?

Nominal ground pressure is a static measurement that considers the weight of the machine as well as its area of contact with the ground. This pressure serves as an indication of the machine's likely impact on soils, all else being equal. This method of measuring ground pressure permits effective comparisons between machine types and predicts the impacts of changes in a machine's configuration on its nominal ground pressure. However, when considering the impacts of forestry machinery on forest soils, other machine characteristics, such as tire specifications and travel speed, and site characteristics, such as soil properties and operating conditions that are not included in the calculation of nominal ground pressure, must be considered. For this reason, the calculated pressure may not relate directly to the actual level of soil disturbance under field conditions.

PASCAL: a tool for calculating nominal ground pressure

FPInnovations has developed a spreadsheet-based calculation tool (PASCAL) to aid in the determination of nominal ground pressure for 15 types of forestry equipment based on the calculation method of Mellgren (1980) (Figure 1.)

The advantage of the CPPA method is that it facilitates relative comparisons between machines. An important assumption made by the CPPA method is that the machine's tires or tracks penetrate the soil to a depth of 15% of the wheel diameter. This determines the surface area (footprint) that is in full contact with the soil, which is then used to calculate the ground pressure. However, depending on soil conditions, the machine tires (or tracks) may not sink to this 15% depth of the wheel diameter. If this 15% depth is not achieved, the footprint area may be reduced and, as a result, the actual machine ground pressure will be higher than what the CPPA calculation indicates. The CPPA method also does not differentiate between the track types that can be installed on bogie axles. Some track models provide an increased contact area.

For these reasons, ground pressures calculated using the CPPA method and by PASCAL should only be considered as relative comparisons between machines, not as a predictor of actual soil disturbance.

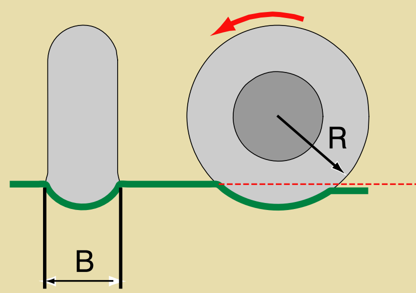
With the PASCAL software the user describes the configuration of existing or proposed equipment (axle weights, machine dimensions, load size, etc.) and then chooses from a range of available tire sizes and track types, as well as additional characteristics of the wheels, chains, and tracks that are stored in the software's databases. PASCAL then evaluates the impacts of changing these characteristics on the nominal ground pressure, as well as the range of ground pressures exerted by alternative types of equipment. Additional information on PASCAL is available on the FPInnovations Web site (www.feric.ca/pascal-en).

Nominal ground pressures for common forestry machines

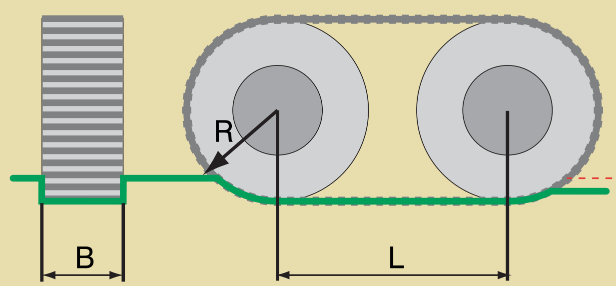
The ground pressure exerted by the rear end of a loaded machine is the key factor when considering the machine's impact on the soil, since the load's weight is carried primarily on the rear axle. For example, a forwarder carrying a full load of wood will see the ground pressure at its front end increase by 7 to 8%, whereas the ground pressure exerted by the rear wheels may increase by 200 to 300%. With a grapple, clambunk, or cable skidder, the load is not entirely supported by the machine; instead, it is dragged, and a portion of the load remains in contact with the ground. As a result, the load has a different impact on the ground pressure. With a fully loaded grapple or cable skidder, the ground pressure exerted by the machine's front wheels will decrease by 20 to 40% as a result of the altered weight distribution, and, depending on the machine configuration, the ground pressure exerted by the rear tires may increase by 150 to 170%.

To calculate ground pressure (p) using the CPPA method, the following parameters are used:

p = ground pressure (kPa)
W = weight on the wheel or track (kg)
R = wheel radius (m)
B = width of the wheel, tire, or track (m)
L = distance between the centers of the wheels in a bogie (m)



$$p = W / (R \times B)$$



$$p = W / [(1.25\ R + L) \times B]$$

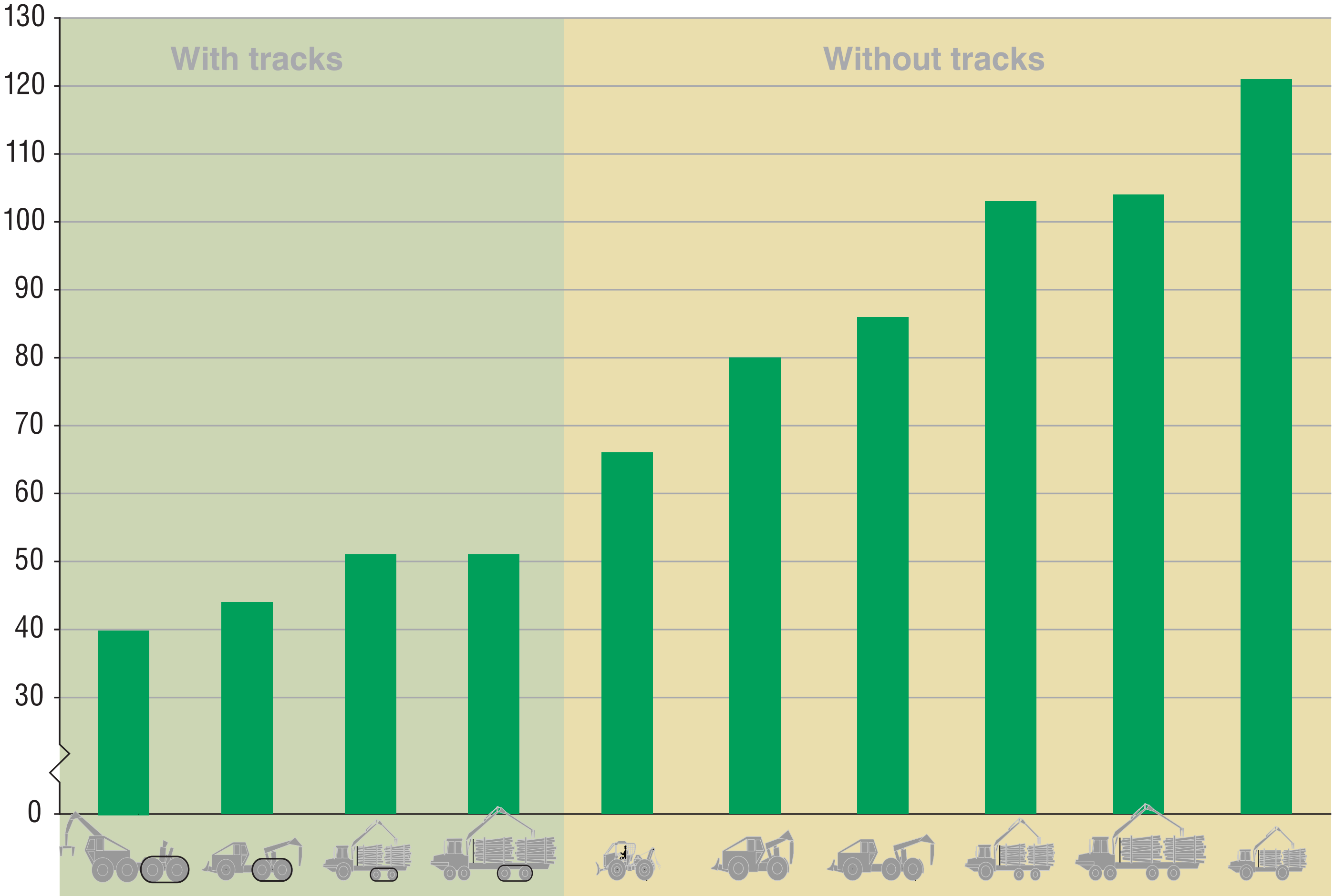
Figure 1. Calculating ground pressures using the CPPA method.

Figure 2. Average nominal ground pressures at the rear axle for a fully loaded machine in several common classes of extraction equipment. Values were calculated using the PASCAL software.

Figure 2 illustrates the average rear-axle ground pressures for a variety of machine types. The values in this graph represent averages for a wide range of configurations (e.g., weight, load capacity, tires) and makes for each machine type.

The ground pressures created by tracked harvesting machines are typically lower than those of comparable wheeled machines. For example, a tracked single-grip harvester or feller-buncher on an excavator chassis will have a ground pressure of approximately 50 kPa, which is similar to the ground pressure at the rear axle of a typical loaded six- or eight-wheeled forwarder equipped with bogie tracks. However, a tracked harvester or feller-buncher moves slowly and will not make multiple passes over the same trail. For this reason, the impacts of this ground pressure on soil disturbance (compaction and rutting) will generally be of little concern during harvesting. If soil rutting occurs during the felling phase, this is a good indication that higher levels of soil disturbance can be expected when the wood is extracted by a skidder or forwarder that exerts comparable levels of pressure, since these machines pass repeatedly over the same ground.

Rear-axle ground pressure (kPa)



Effect of tire size and tracks on nominal ground pressure

Proper machine selection and modifications to the running gear are important tools for reducing the potential soil disturbance. However, there are a few options for modifying the nominal ground pressure of existing equipment; the main options relate to tire size, track width, track pad configurations and the addition of bogie or wheel tracks.

The use of wider or larger-diameter tires can significantly reduce a machine's ground pressure (Heidersdorf and Ryans 1984, Meek 1994). In both cases, the increased tire size increases the tire's footprint, thereby increasing the soil contact area over which the machine's weight is distributed. A wider tire increases the footprint by widening the contact area; a larger-diameter tire increases the footprint by lengthening the contact area. Figure 3 provides an example of how changing tire size affects ground pressure at the rear axle of a four-wheeled grapple skidder. We have only presented results for the rear axle, as this axle will have the highest axle load (and thus, will produce the greatest ground pressure) when the machine is loaded.

For machines with bogies, such as forwarders and some large skidders, the addition of bogie tracks can significantly reduce the nominal ground pressure because the tracks increase the machine's footprint area by providing a larger contact area over

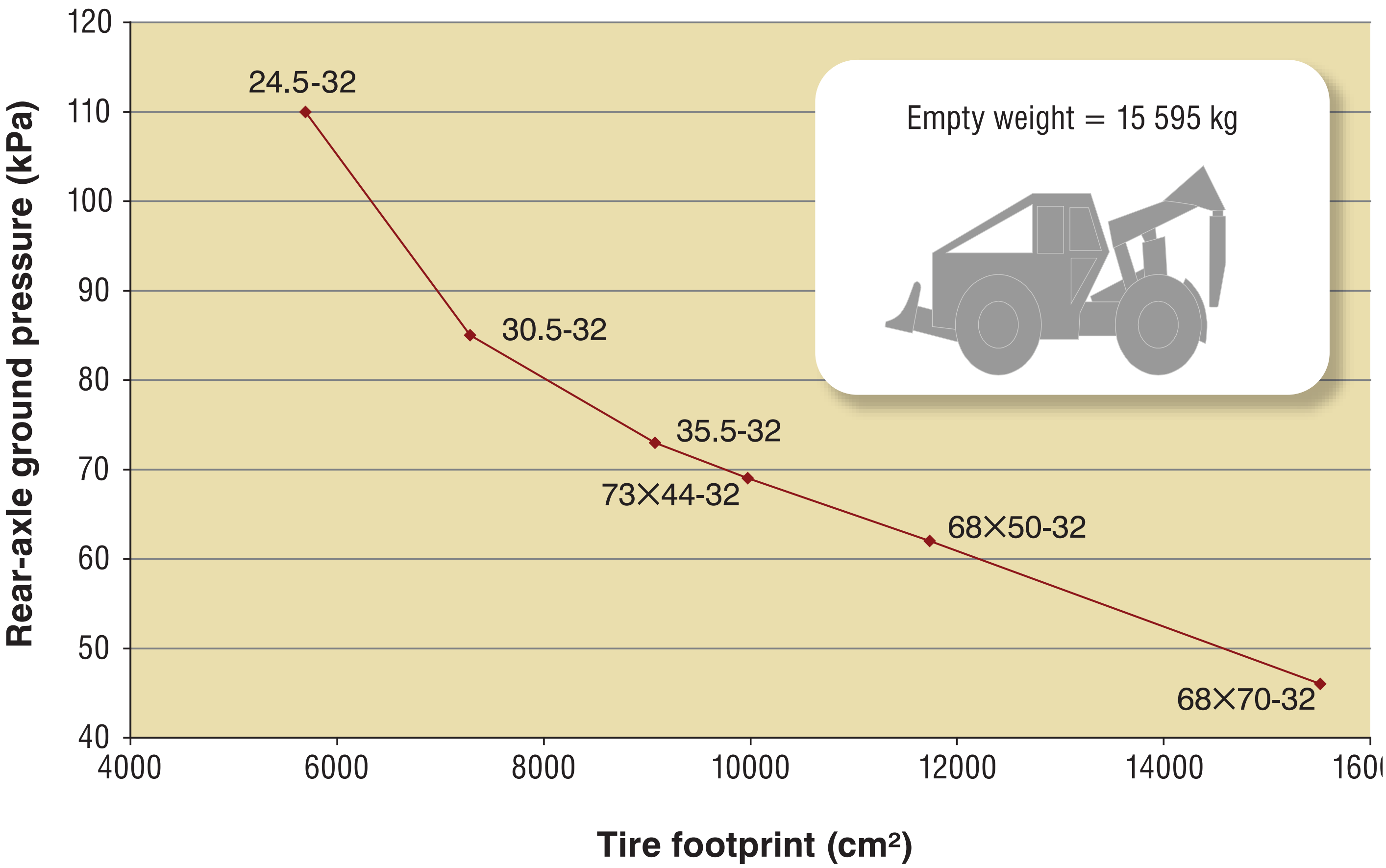


Figure 3. The effects of changing the tire footprint on the rear-axle ground pressure exerted by a typical loaded four-wheel grapple skidder. The values were calculated using the PASCAL software.

which the load is distributed. This can be particularly valuable for the rear axle of fully loaded forwarders. For forwarders working in commercial thinning or other partial cutting applications, it may be difficult to use wide tires because of the narrow spaces between trees, so the use of tracks is an important way to reduce ground pressure. Adding tracks to a bogie axle can reduce the ground pressure by approximately 50%, as Figure 4 shows using the example of a 14-tonne forwarder.

Tire chains do not increase a machine's flotation, and slightly increase the machine's ground pressure due to their added weight. The primary function of chains is to increase traction, thereby reducing wheel slippage and decreasing tire wear. A certain amount of slippage is inevitable, but excessive slippage increases rutting and soil compaction, reduces productivity, and increases fuel consumption. Single-tire tracks are also available, and can increase the machine's footprint area; as a result, they decrease nominal ground pressure.

Changing tire size and adding tracks on bogies are common strategies to reduce ground pressure. However, these modifications can also affect operating costs, productivity, fuel consumption, and operator comfort. Sutherland (2005a) provides a more detailed discussion of the effects of these and other variables.

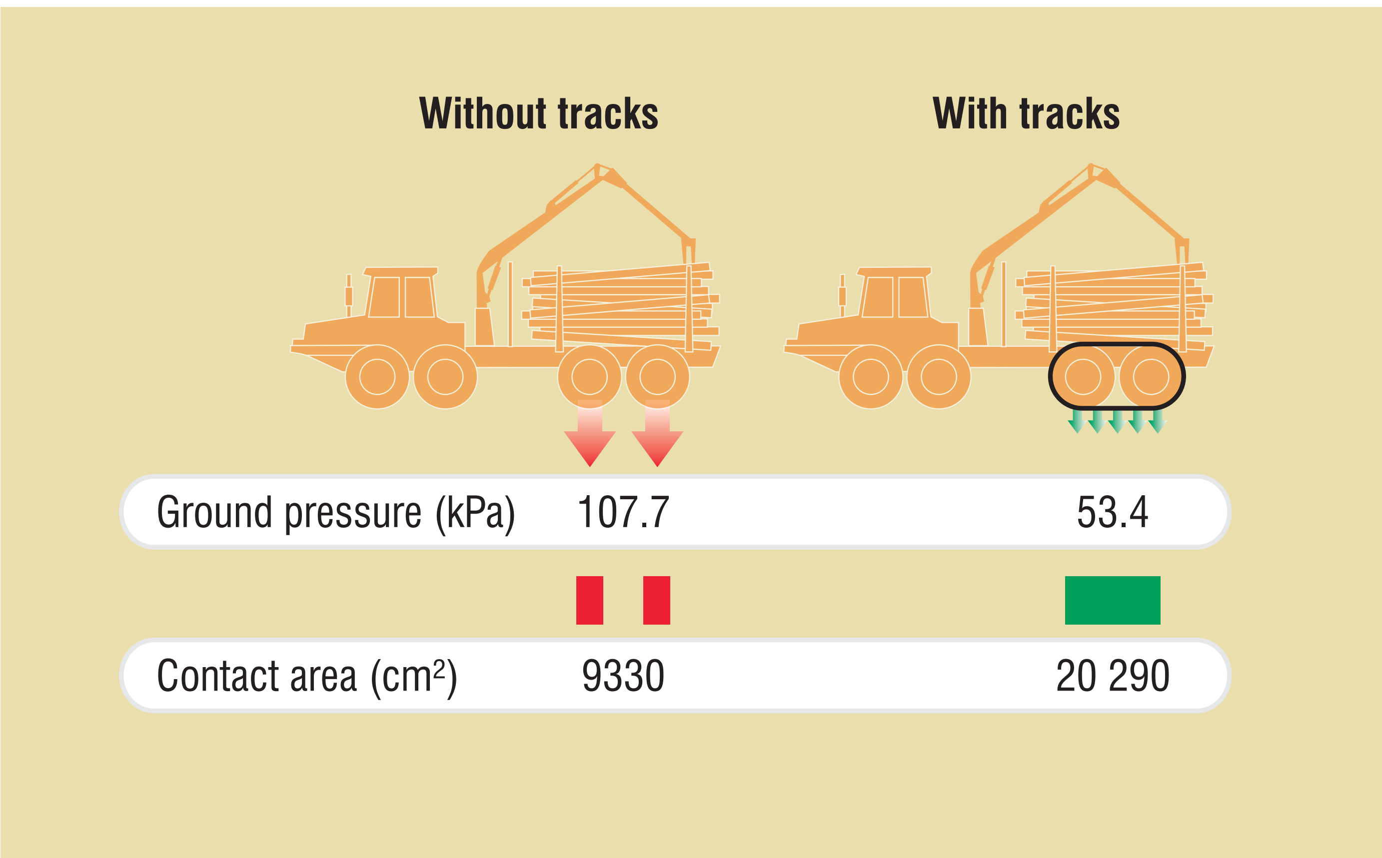


Figure 4. Nominal ground pressure exerted by a fully loaded 14-tonne eight-wheeled forwarder with and without bogie tracks. Values were calculated using the PASCAL software.

Implementation

When evaluating the potential impact of a particular machine configuration on soil disturbance, it is important to consider the effects on the machine's nominal ground pressure. Other factors, such as the number of trips the machine will make over a given stretch of trail to extract the wood, must also be considered. Choosing a smaller machine may reduce ground pressure compared with a bigger machine, but if the smaller machine requires multiple trips to extract the same amount of wood, there may be no net benefit to choosing the smaller machine.

The relative comparison of nominal ground pressure for forestry equipment is facilitated by the PASCAL software, developed by FPInnovations. Knowing the nominal ground pressure of equipment and understanding the options that are available to reduce it will let you improve the efficiency and reduce the environmental impact of your harvest operations.

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