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GROUND PRESSURE FORWARDER TRIALS: ASSESS BENEFITS IN REDUCING WHEEL RUTTING

Francesco Neri*
Department of forest science and technology in forestry
Via S. Bonaventura, 13 – 50145 Firenze (Italy)
francesco.neri@unifi.it

Raffaele Spinelli
Harvesting Research Group
CNR/IVALSA
Via Madonna del Piano - Palazzo F, I -50019 Sesto Fiorentino (FI) – Italy
spinelli@ivalsa.cnr.it

John Lyons
Coillte, Sullivans Quay, Cork –Ireland
john.lyons@coillte.ie

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Abstract: *Reduced tyre inflation pressure has been extensively used in timber haulage industry, with significant benefits in the control of rutting on forest roads during timber haulage. Research in Canada and Sweden has shown significant reduction in the rutting caused by haulage trucks on forest roads, when used with reduced tyre pressures vis-à-vis normal tyre pressures. Reduced tyre pressures also allow for timber haulage to be carried out over a longer time during the 'thaw period' in winter. Research in Ireland has also quantified the potential benefits of reduced tyre pressures in minimisation of fatigue damage on forest access roads, i.e., significant increase in the number of wheel passes prior to failure by cracking and rutting.*

The benefits and best practices in the use of reduced tyre inflation pressures on forwarders are as yet unclear for many forest roads with varying soil substrata and moisture regimes. The aim of this study was therefore to provide data that could be useful in determining the best practice.

Timberjack 810 forwarder was used. This is the most common forwarder type in Irish Forestry and in other European country. The forwarder was fitted with both 600mm wide tyres (4 of) and 700mm wide tyres (4 of). The forwarder, together with a full load of timber was transferred to the site and payload was accurately measured so that trials can be run with full payload and with half payload.

Analysis of the soil (moisture content, cone penetrometer measurements, shear vane tests) were carried out so that a detailed description of the site could accompany the results. Trial location was in Ireland in the Midlands, near Clonaslee in Slieve Blooms Forest, a highly forested area, close to where the forwarder operates generally. This has been typical of a soft, shallow peat based site described as peat podzol.

The work was funded by COFORD (Council for Forest Research and Development in Ireland) and conduct in cooperation between the University of Florence, Coillte (the Irish forestry board) and CNR (National Research Council – Italy). The aims of this study were: a) to quantify the effects of reduced tyre pressures on rutting on soft soils, when compared to normal recommended pressures; b) to quantify the significance of load size variation on rutting potential, in order to assess the potential benefits of using reduced load size as a strategy to minimise rutting; and c) to assess the effect of tyre size (600 mm and 700 mm wide tyres) in the potential control of rutting.

In the case of rutting, the best results (minimum depth of ruts) were obtained, as expected from wider tyres, at lowest tyre pressure, 1 bar. However on a cautionary note this low tyre pressure may not be acceptable or sustainable in normal forwarding operations over time.
The results again confirmed the benefits of the 700mm wide tyres over the 600mm tyres in reducing rut depth. The rutting caused by the 600mm with tracks was similar to the 700mm tyres at a reduced pressure of 2 bar. Where traction is not a problem, perhaps in the case of flat raised bog in the summertime, then there is an advantage to using the 700mm tyres without band tracks. When the pressure is reduced to 1 bar in the 700mm tyres then these perform better than the 600mm with tracks. The results also confirmed the benefits of using reduced load size in preventing rutting.

1. Introduction

Reduced tyre inflation pressure has been extensively used in timber haulage industry, with significant benefits in the control of rutting on forest roads during timber haulage. Research in Canada and Sweden has shown significant reduction in the rutting caused by haulage trucks on forest roads, when used with reduced tyre pressures vis-à-vis normal tyre pressures. Reduced tyre pressures also allow for timber haulage to be carried out over a longer time during the 'thaw period' in winter. Research in Ireland has also quantified the potential benefits of reduced tyre pressures in minimisation of fatigue damage on forest access roads, i.e., significant increase in the number of wheel passes prior to failure by cracking and rutting.

The benefits and best practices in the use of reduced tyre inflation pressures on forwarders are as yet unclear for many forest roads with varying soil substrata and moisture regimes. The aim of this study is therefore to provide data that could be useful in determining the best practice.

The work was funded by COFORD (Council for Forest Research and Development in Ireland) and conduct in cooperation between the University of Florence, Coillte (the Irish forestry board) and CNR (National Research Council – Italy).

2. Objective

The objectives of this study are:

- To set up trials to quantify the effects of reduced tyre pressures on rutting on soft soils, when compared to normal recommended pressure and compare these effects with that of wider tyres and the use of band tracks.
- To document potential problems such as tyre/rim problems, tyre damage/punctures.
- To quantify the significance of load size variation on rutting potential, in order to assess the potential benefits of using reduced load size as a strategy to minimise rutting.
- To assess the effect of tyre size (600 mm and 700 mm wide tyres) in the potential control of rutting.

3. Materials and Methods

A Timberjack 810 forwarder was used, as this is the most common forwarder type in Irish Forestry.
The forwarder was fitted with both 600 mm wide tyres (4of) and 700 mm wide tyres (4of). The forwarder, together with measured timber payload was transferred to an experimental site in the Midlands, in the Slieve Blooms, a highly forested area of Ireland.

Figure 1: Forwarder Timberjack 810

The experimental site was in Kilinaparson property, near Clonaslee in Slieve Blooms Forest, the property of Coillte (the Irish forestry board) who facilitated this work - the machine was hired from Coillte. The experimental site was a typical soft, shallow peat based soil (peat podzol). Measurement of the soil properties (viz., moisture content, cone penetrometer resistance, and soil shear resistance) was conducted so as to provide a detailed description of the site that was to accompany the results.

Figure 2: Moisture content analysis

A portable air compressor was hired and retained on site for use in the variation of machine tyres pressures. Wheel contact area was measured at different axle loads and at different tyre pressures. Individual axle loads were measured using a set of portable electronic weighing pads, while payload in the forest was evaluated by calculating the average log weight and the number of logs in the load.

Forwarder wheels were re-arranged for the trials. The 600mm tyres were fitted along the left side of the machine and the 700mm tyres on the right side so that comparative information on the benefits of increasing tyre diameter in reducing wheel ruts could be assessed.

An experienced forwarder operator was used to achieve repeatability in machine control on the wheel track. The load was uniformly distributed on the trailer and the same travel speed was employed in all tests so as to discount the dynamic effects of machine on rutting. Operator also assisted in machine preparation, changing wheels, fitting and removing, inflating and deflating tyres.

The test area was approx. 0.7 ha and was very soft, hindering the machine from turning at the end of each test run. The tests were therefore carried out by driving forward and reversing in the same track. A laser level was used to accurately measure the successive wheel rutting.

Figure 3: Laser level

Test areas were marked out, six adjacent parallel strips, each 20m long. Markers were laid down every 5 metres along the test area, indicating where rut depth measurements were to be taken. These measurements were repeated for each test track. Soil moisture content and cone penetrometer data was measured in the rut at the test locations. Soil shear vane measurements were taken alongside the wheel tracks as shown on the diagram below.

Figure 4: Test area

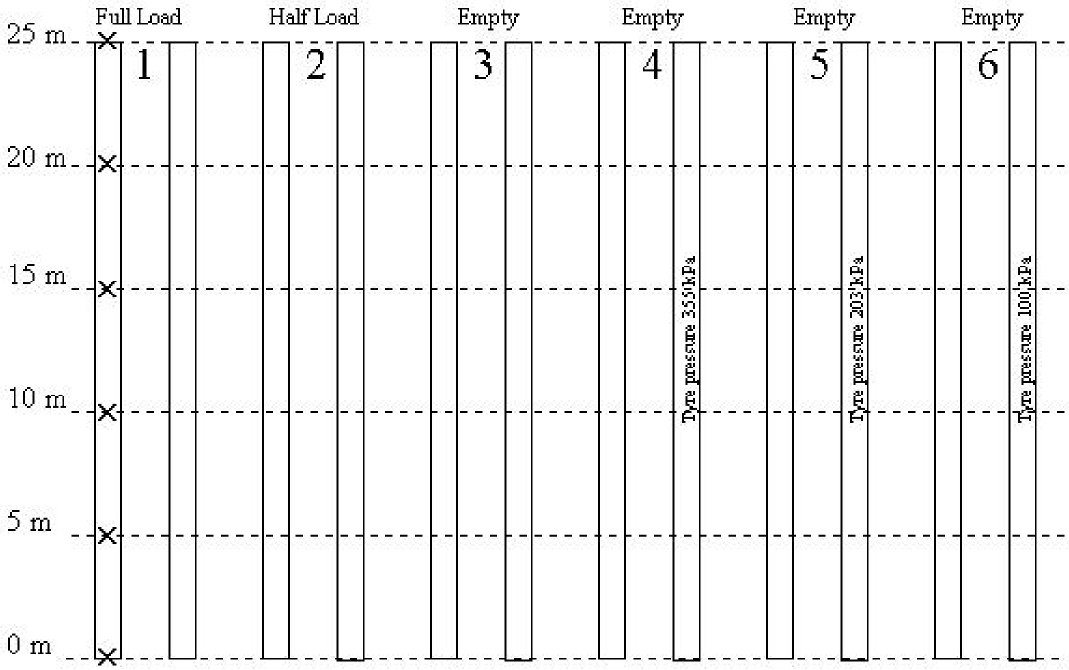


Figure 5: Illustration of the experimental set-up in which numbers 1 to 6 indicate the different test tracks. Tyre inflation pressure was set at 355 kPa for tracks 1 to 3, while pressure on the right hand side wheels on test tracks 4, 5 and 6 were as indicated. Wheel band tracks were fitted on left hand side wheels at 355 kPa inflation pressure in all cases. Rut depths were measured at locations marked × using a laser level.

Each test line was divided into four segments to allow for replications. Measurements with penetrometer were taken along the ruts in all the lines before the initial forwarder pass. Cone penetrometer readings and rut depth measurements were measured following each machine pass. The number of passes was up to six. Shear-vane tester and moisture content readings were taken throughout the site to assess the variability in localised areas.

It was expected that the trials would show significant benefits in terms of reduced rutting at lower tyre pressures and smaller payloads. It was unknown what relative benefits might accrue at the different stages of reduced pressure. Comparative rut measurement data were produced for 600 mm and 700 mm wide tyres; and also 600 mm plus tracks v. 700 mm tyres only.

4. Results

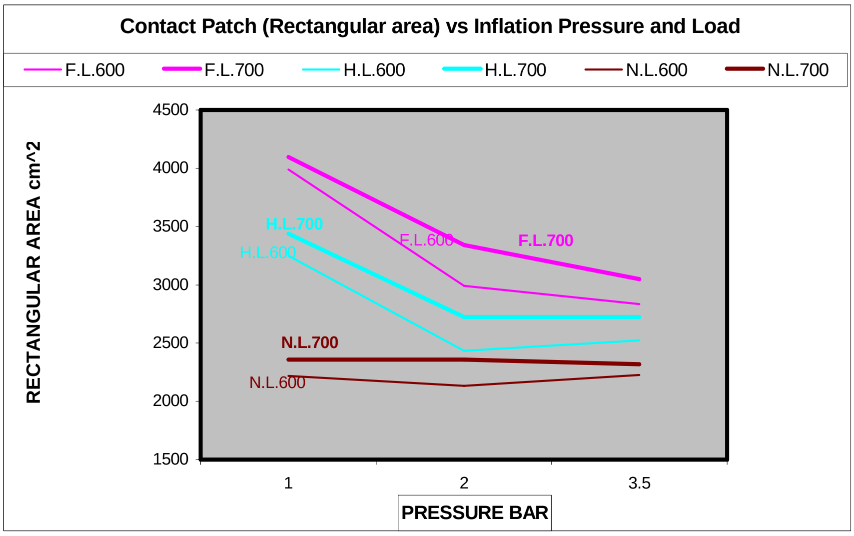
4.1 Evaluation of Tyre Contact Areas

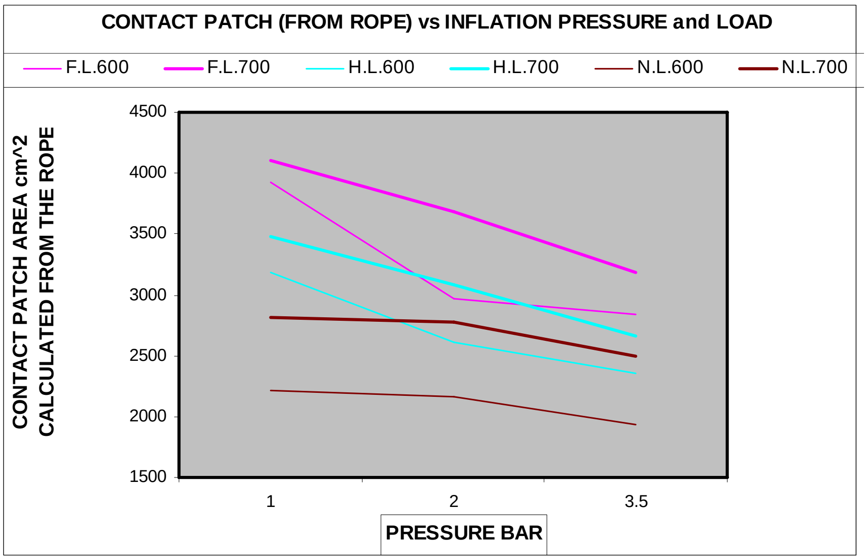
This was carried out in order to determine the relative differences induced through reduced tyre pressures and through varying load sizes. These measurements were taken at three different pressure settings, 3.5 bar, 2.0 bar, 1.0 bar, when trailer was fully loaded (**F.L.**), half loaded (**H.L.**) and with no load (**N.L.**). Full load comprised 8.62 tonnes of 4.9m long saw log (38 logs), half load being 19 logs.
Data was collected by two methods, both on a flat concrete surface.

1) Four round bars, 19mm diameter, were rolled against the tyres in the form of a rectangle and when seen to be lined up (opposite bars parallel to each other), the rectangle sides were measured. These lengths were then used to calculate an area representing the contact patch.

2) A rope of 31mm diameter was pulled tightly around the tyre at ground level and the length of the rope was measured. This length was used as the circumference of a circle to calculate an area that represents the contact patch.

Results are plotted in the following graphs. First graph is from the data collected by the round bars method while the second graph is from the data collected using the rope. The rope method is considered to be a somewhat better representation of how the contact patch increases with load size and with reduced pressure.





Figures 6 and 7: ***Measurements were taken under trailer tyre and show very little difference in contact area at the different tyre pressures with no load, indicating that the tyre has not deflected. Greatest difference occurs with full load and at 1 bar pressure, when tyre looked visibly under inflated***

From the first scenario to the second, the contact patch increased in length by 47.7% and 61.5% while it increased in width by 21.2% and 9.2% for the 600mm tyres and the 700mm tyres respectively. The average increase in length was over 50% while the average increase in width was approx. 15%, resulting in an overall increase in the contact area of 77.75%.

4.2 Cone penetration resistances analysis

On each experimental line, ten cone penetration resistance (CPR) readings were recorded per machine traffic treatment, for every 10 mm increase in depth of the soil profile 0 – 600 mm. These were utilised in the development of the CPR profiles. Generally, CPR increased with machine traffic, and the increment was considerable in the top 500 mm of the forest floor. It may be concluded that the traffic by forwarder machine generally caused compaction to a depth of at least 400 mm. By increasing load, the intensity of soil compaction also increased.

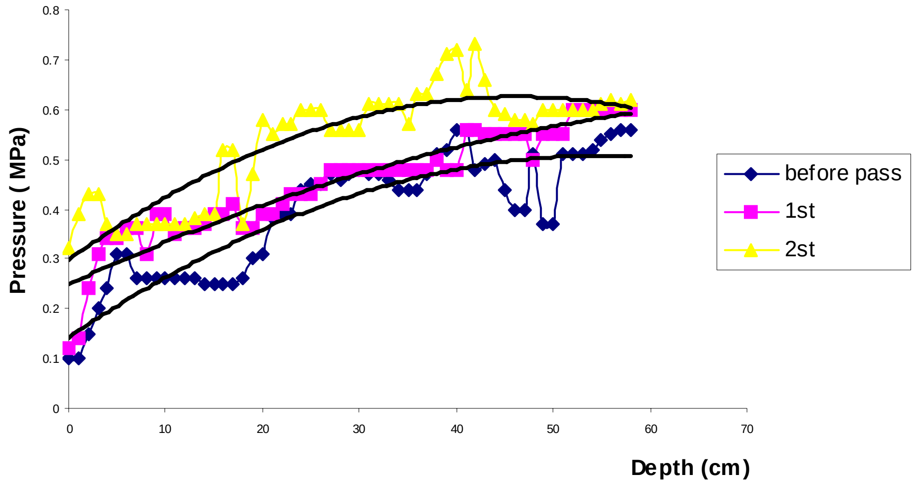


Figure 8: ***Cone penetration resistance profiles including best fit lines for 700 mm wheel with band track and 200 kPa tyre inflation pressure and empty load***

4.3 Shear-vane test and moisture content.

The figures obtained give some general indications about the soil resistance and its water content. They show the variability in the site test area, even in much localised spots. There are some areas in which the soil resistance is good (60 – 70 – 80 kPa for the Shear Test) and others nearby where the figures are much lower (kPa 25 – 35), even on the same line.

The moisture content shows us that the soil is very wet (exceeding 100% water in cases) especially in the 3rd, 4th and 5th line. Due to this variation is very difficult to make some detailed comparisons. It is likely that in those areas where the value of the Shear Vane Test is very high there is the effect of the vegetation roots. Some follow up tests confirmed this at the end of the trial. Some comparison of the lines, noting the values of the Shear vane test and of the moisture content show the following;

- **Lines 1 - 2**: Medium Shear vane test results (kPa 40 and more) and moisture content. (more than 70 %).
- **Line 3**: Good Shear Vane test result, more than 70 kPa, (possible roots effect), but it is very wet (100 %).
- **Line 4 – 5 – 6**: The soil seems very soft and wet (Shear Test around 30kPa and moisture content 95%).

4.4 Rut depth analysis

Figure 9: Rut depth analysis

The compaction effects increased from the first pass to the second and were noted down to 40 cm though the greatest increase was in the top 10 cm. Rut data measurements were plotted. An example of some of the results obtained is shown in two graphs, Figures 10 - 11.

- Tyre pressure of 3.5 bar vs 2 bar vs 1 bar (Figure 10)
- 700mm wide tyres vs 600mm wide tyres vs band tracks (Figure 11)
- Full load vs Half Load

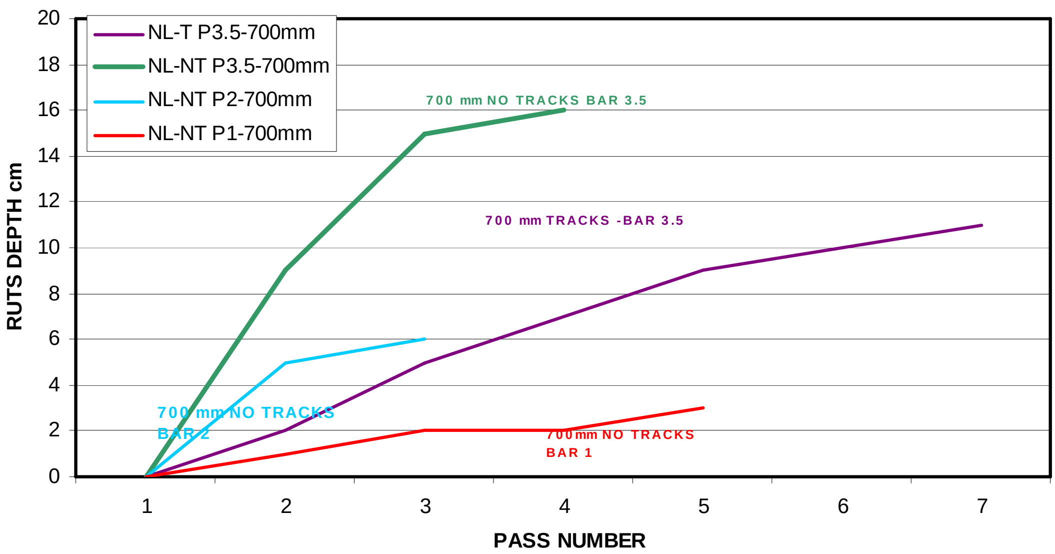


Figure 10: Effect of reduced tyre pressures on rutting, 700mm wide

Figure 10 shows the benefits of reducing tyre pressure.

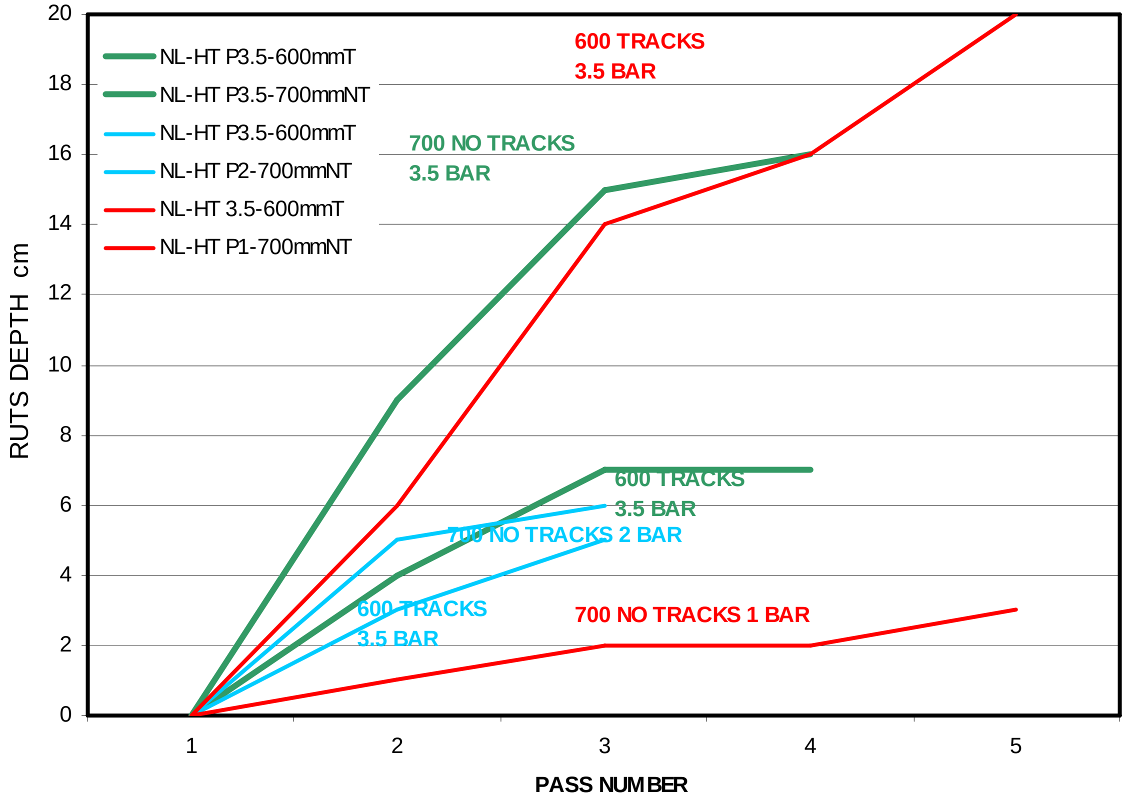


Figure 11: Comparison, 600mm tyres + band Tracks vs 700mm wide tyres

The lines coloured similarly in Figure 11 are matched pairs, representing the left hand side (600 mm wide band tracks) and the right hand side of machine, (700mm wide tyres only with variable tyre pressure).

5. Conclusions

The following specific conclusions are apparent from this study. The tyre load and inflation pressure had a considerable effect on CPR to a depth of 500 mm. The full load and high inflation pressure treatment caused greater changes in CPR than were caused by lower loads, lower inflation pressures, or combinations with lower loads and lower inflation pressures.

Variability in the site conditions is the reason that some results are not in line with the expected trend and this serves to explain irregular readings. This was seen to occur over short stretches (couple of metres) and was sometimes apparent between the two sides of the machine.

In the case of rutting, the best results (minimum depth of ruts) were obtained, as expected from wider tyres, at lowest tyre pressure, 1 bar. However on a cautionary note this low tyre pressure may not be acceptable or sustainable in normal forwarding operations over time.

The results again confirmed the benefits of the 700mm wide tyres over the 600mm tyres in reducing rut depth.

The rutting caused by the 600mm with tracks was similar to the 700mm tyres at a reduced pressure of 2 bar. Where traction is not a problem, perhaps in the case of flat raised bog in the summertime, then there is an advantage to using the 700mm tyres without band tracks.

When the pressure is reduced to 1 bar in the 700mm tyres then these perform better than the 600mm with tracks.

The results also confirmed the benefits of using reduced load size in preventing rutting.

6. References

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