

TECHNICAL NOTE

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SUMMARY

This Technical Note discusses the benefits of traction aids in forestry. Generic types of traction aids and their effects on machine travel are described. Guidance is provided on when and where traction aids should be used along with their characteristics under different operating conditions and their selection according to site. Advantages and disadvantages of using traction aids are listed and alternatives to achieving similar benefits through operational best practice that allows efficient timber harvesting while safeguarding the condition of the site are also described.

INTRODUCTION

The main reasons for fitting traction aids to forest machines are to increase the grip between machine wheels and the ground surface and to spread load weight. The area of the wheel in contact with the ground is called the 'footprint' area. If traction aids have a greater area in contact with the ground than wheels alone the footprint size increases and ground pressure exerted by the machine is reduced. Traction aids can also increase machine stability, improve flotation and protect tyres (Figure 1). Inappropriate selection of traction aids can have a negative impact on forest soil, water, the standing crop, and on machine and operator ergonomics. Appropriate traction aid selection for use with a machine in a given situation is therefore very important.



Figure 1

Forwarder converted to carry out ground preparation fitted with bandtracks on the front and rear bogies.

TYPES OF TRACTION AIDS

Tyres

Traction is created where a machine makes contact with the ground; therefore the first consideration for increasing machine traction is the tyre specification. Tyres are available in a diverse range of specifications from a number of manufacturers. Externally, different tread patterns impart different flotation, grip, load distribution and self-cleaning properties to the wheel; changing tyre specification can result in gains in traction. If further traction is required then ancillary traction aids should be considered.

Wheel chains

Wheel chains are a robust, easy to transport, quick to fit means of gaining additional traction (Table 1, Figure 2). Correct fit of chain to tyre is important to obtain maximum benefit and avoid damage to the tyre through slippage.

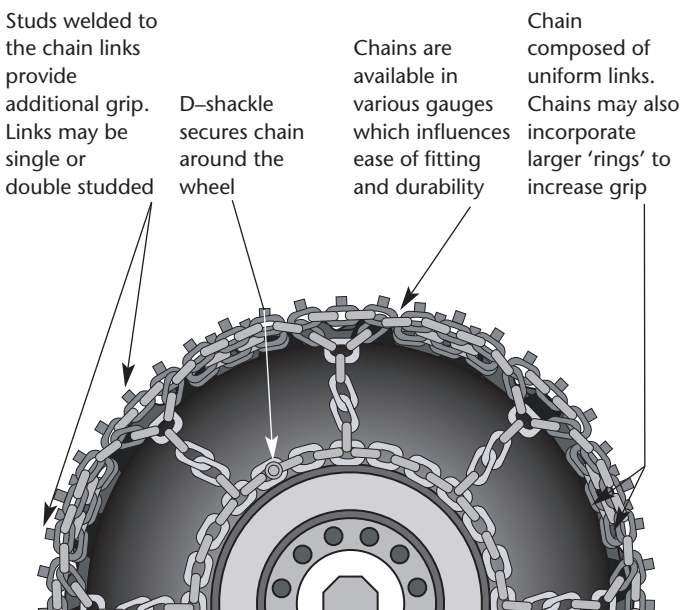
The incorporation of rings into tyre chains provides increased grip although this may cause greater ground disturbance and operator discomfort due to a rougher ride. Special care is needed when fitting wheel chains to machines with bogie wheels and those with articulated steering, as the clearance between the adjacent wheels may preclude the use of some chain types. Chains do not have the potential to significantly influence the flotation of the machine because, unlike bandtracks, there is no appreciable increase in the machine footprint area.

Table 1 Wheel chain characteristics.

Wheel chain description	Assembly of specialised chain links and/or rings fitted over the bare tyre to provide additional traction and tyre protection. Relatively lightweight option for increasing traction.
Effect on traction	Friction between the wheel and ground surface is increased and chains with welded studs on the linkages aid grip despite mud build-up. Chains create less rolling resistance than tracks.
Effect on flotation	Chains do not significantly aid flotation although preventing wheel slip can prolong the use of access routes.
Effect on ground disturbance	Gaining extra traction through the use of chains but the footprint area remaining unaltered means that a scouring effect can occur on routes where wheel slip occurs.

Figure 2

Common features of wheel chains. Note that slack should be avoided; correctly tensioned chains will jingle slightly when driving.



Monotracks

A monotrack is similar to a bandtrack, but rather than fitting to a pair of bogie wheels a monotrack attaches around a single wheel. There is little experience and information on the use of monotracks (also called ‘wheel tracks’) as a traction aid in UK conditions and little is known about their effects on traction, flotation and ground disturbance (Table 2).

Bandtracks

Bandtracks increase machine traction and flotation. A variety of specifications provide the machine with

Table 2 Monotrack characteristics.

Monotrack description	Traction aid made up of metal plates connected by heavy duty linkages that fit over a single wheel.
Effect on traction	Machine traction is increased. See bandtrack characteristics (Table 3).
Effect on flotation	Increased, although footprint area is not as substantially increased as when using bandtracks.
Effect on ground disturbance	Little experience of use in UK conditions therefore their effects on ground disturbance are largely unknown.

different characteristics (Table 3, Figures 3, 4 and 5). Bandtracks add significantly to the overall weight of the machine as each track may weigh a tonne or more but because the machine’s footprint area is increased (Figure 3) ground pressure can be reduced.

The footprint area of a forest machine is influenced by the number of wheels, tyre pressure, tyre dimensions, tyre tread pattern and the use of traction aids that increase the area through which the weight of the machine is transferred to the ground.

A wheel is designed with a round profile to roll smoothly, allowing efficient machine movement. Attaching bandtracks reduces the ability of machine wheels to roll freely, an effect known as rolling resistance. In recent years developments in track plate design have attempted to overcome rolling resistance, while still maximising the benefits of tracks for improved traction and flotation.

If fitted correctly the track will be in intimate contact with the wheel with no slippage between the tyre and the track. If slippage does occur it can result in tyre wear. Correctly fitted tracks will prolong the life of the tyre, protecting it from damage during use. Two principal types of bandtrack design are commonly available in the UK: those with a side link and those that feature side paws (see Figures 4 and 5). A number of bandtrack manufacturers produce their own version of these track types in a range of models to suit different machines, tyre specifications and operating conditions.

Side links and side paws

Bandtracks have traditionally been designed to curve round the wheel profile with the ends of each track plate partially wrapping ‘around’ the tyre. The curved plates are connected with forged links at the end of each plate, as

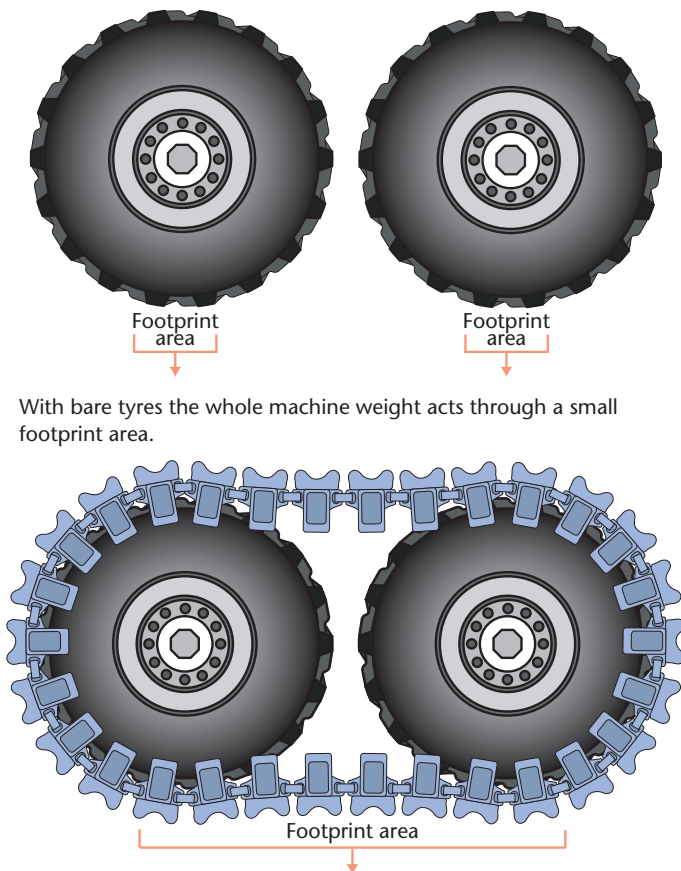
Table 3 Bandtrack characteristics.

Bandtrack description	Metal plates connected by heavy-duty linkages that fit over a pair of bogie wheels. Varying designs and plate profiles give different flotation, traction and steep ground working capabilities to the machine.
Effect on traction	Machine traction is increased. Narrow track plates convey the greatest traction benefits, but offer minimal flotation. Lugs welded onto the outside of the track provide increased grip and prevent side slippage but prolonged travel along forest roads has potential to erode the surface. Track plates with an 'L' or 'C' shaped cross-section help the machine to gain extra purchase, although their aggressive scouring effect is only appropriate on stable and firm ground.
Effect on flotation	Flotation is increased as the footprint area is greater than that of the wheels. The broader the bandtrack plates, the greater the increase in flotation; some tracks are designed with broad plates and the smallest gap possible between plates to maximise the machine's footprint area.
Effect on ground disturbance	The degree of disturbance varies with track specification. Aggressive tracks designed to give the greatest traction advantage can disturb the soil significantly. This can be a particular problem when the machine is turning onto the forest road from the harvested site. Track plate profiles that are folded at the ends minimise this effect.

shown in Figure 4. Side link tracks are best suited to machines that carry out minimal movement between sites on forest roads as the position of the track plate link ends can cause disturbance, but they do provide a lighter weight option than side paw tracks and maintain good traction and flotation.

Figure 3

Comparison of machine footprint area for bogie wheels with and without bandtracks.



Side link tracks are comparatively simple in their design and cheaper than tracks with side paws. They are well suited to a wide range of forest machinery. Recent design developments include the production of tracks substantially wider than the supporting tyre, allowing improved flotation. These tracks have track plate links positioned closer to the crown height at the side (outside radius) of the tyre and therefore include side paws to keep the track on the tyre. Side paws allow a convenient way of extending the track plate to greater than wheel width while still maintaining firm contact with the sidewall. They also support the track on the tyre when exposed to lateral forces during turning and travel on side slopes, and reduce ground scuffing by the track plate ends and rolling resistance.

Figure 4

Common features of bandtracks that include side links.

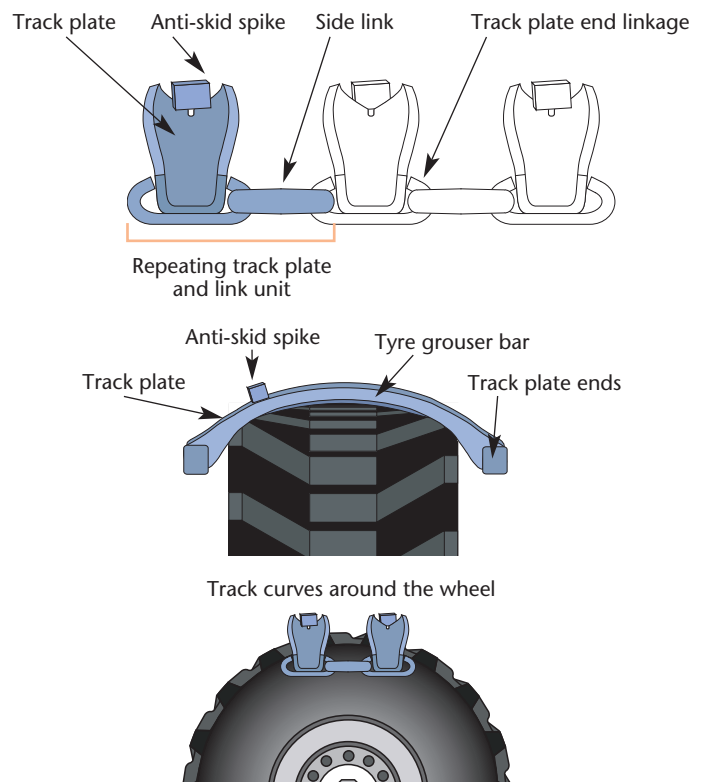


Figure 5

Common features of bandtracks that include side paws.

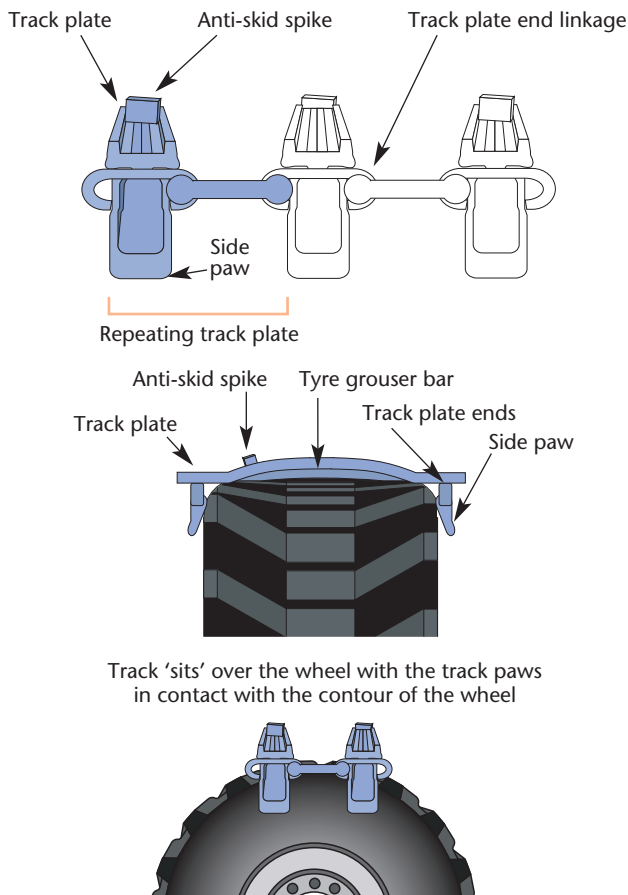


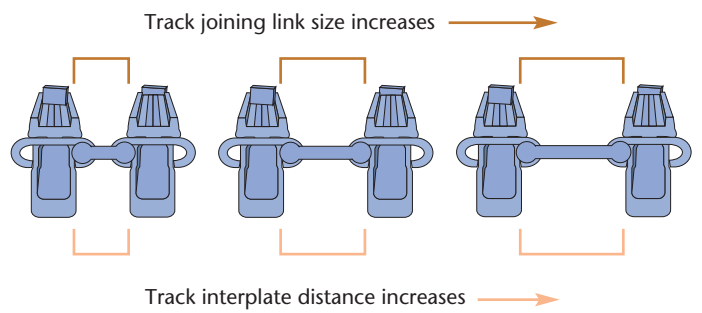
Plate spacing

Track plates should ideally follow a curved profile around the wheel to reduce stress on the machine transmission. Track plates wider than the machine wheels have flotation benefits, but stress is placed on the bandtrack and the machine transmission as the track effectively acts as a lever multiplying lateral force through the wheel or bogie. Anti-skid 'spikes' or 'lugs' give lateral grip to the track, helping to prevent lateral movement on side slopes; they can be positioned at the side of the plate enabling them to provide grip while preventing them from standing proud of the plate at its centre. In this way the potential for damage is reduced when travelling on stone surfaced roads. With both side link tracks and side paw tracks the spacing between the track plates influences the flotation and traction characteristics of the track. The space formed between adjacent plates is governed by the plate design and the link size. The longer the forged links between the plates the greater the interplate distance and the more aggressive the track. As the gap between the track increases, flotation reduces (see Figure 6).

Shorter links equate to a greater track surface area, increasing the flotation of the track and increasing surface

Figure 6

Plate spacing increase with link size.



contact with the tyre which prevents slippage. However, weight and cost increase as more plates are required to make up each track. The greater distance between plates also helps the track shed sticky mud on soils with high clay content.

Double wheels

Double wheels are used to gain extra flotation by increasing the footprint area of the machine, particularly with skidders; experience of using double wheels with forwarders is not widespread. The additional machine width has operational implications for the management of the work site.

USING TRACTION AIDS IN FORESTRY

Principles of ground pressure

The ground pressure of a forest machine is influenced by the footprint area (see Figure 3), the weight distribution and the design of the parts in contact with the ground.

Mean ground pressure exerted by the machine can be calculated, assuming a moderate sinkage rate of 15%, using the following formula.

$$P = \frac{W}{R \times B}$$

where:

P = mean static ground pressure (kg/cm²)

W = wheel load: total weight/number of wheels in contact with the ground

R = unloaded tyre radius (cm)

B = tyre width (cm)

Worked example

For an 8-wheeled machine with total weight of 18 000 kg (18 metric tonnes) and tyres of dimension 60 cm unloaded radius, 70 cm width, the mean ground pressure will be:

$$\frac{W \text{ (kg)/no. of wheels}}{R \text{ (cm)} \times B \text{ (cm)}} = \frac{18\,000 \text{ kg}/8}{60 \text{ cm} \times 70 \text{ cm}}$$
$$= \frac{2250 \text{ kg}}{4200 \text{ cm}^2} = 0.54 \text{ kg/cm}^2$$

The following formula is useful in comparing change in machine ground pressure with bandtracks fitted.

$$P = \frac{W}{B \times (1.25 \times R + L)}$$

where:

P = mean static ground pressure (kg/cm²)

W = wheel load: total weight/number of points of contact with the ground

B = track width (cm)

R = track wheel radius (cm)

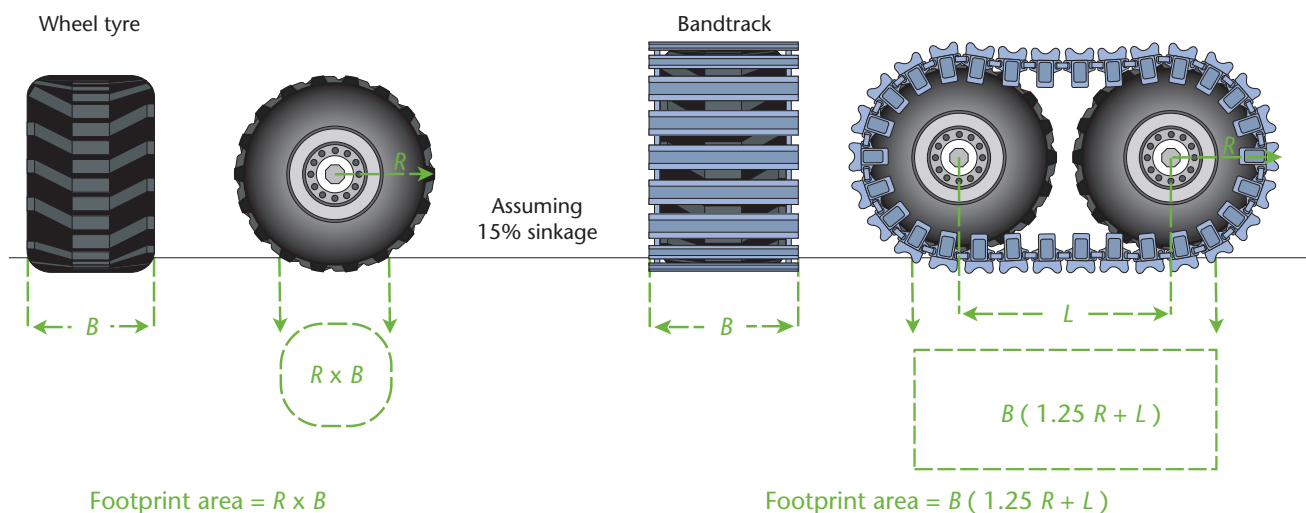
L = distance between track wheel centres (cm)

The calculations in Figure 7 assume a 15% sinkage rate and include a correction factor to account for interplate gaps of 25% of the bandtrack area. The formula for calculating ground pressure of a tracked machine includes a multiplication factor of 1.25, assumed to allow for the area of the track between the wheel centres on the bogie.

Despite the theoretical reduction in static ground pressure there may be less of a benefit achieved due to the many variables involved including the ground conditions, ground profile, slope and dynamic loading of the machine.

Figure 7

Diagrammatic explanation of formulae. Source: P. G. Mellgren, 1980: *Terrain classification for Canadian forestry*.



Ground disturbance

Wheel slippage is a major contributory factor to rutting on access tracks. Increasing machine flotation and traction through the use of traction aids can reduce wheel slip and wheel spin. The likelihood of soil damage varies with soil type.

SELECTION OF TRACTION AIDS ACCORDING TO SITE

As explained, the operational characteristics of traction aids vary with their specification. Bandtracks offer widely different operating advantages and these are often opposing, e.g. a narrow, widely spaced track plate will confer good grip but poor flotation, while a broad plate profile with narrow spacing between plates has far better flotation but with less effective grip. It is not possible to make specific traction aid recommendations for a given machine since site terrain and ground conditions vary considerably, offering unique circumstances. Selection of appropriate traction aids must be made on a case-by-case basis; Table 4 offers guidance from a number of example site types.

ADVANTAGES AND DISADVANTAGES OF TRACTION AIDS

Advantages and disadvantages of using traction aids are shown in Table 5. A decision on the most appropriate option requires careful consideration of the many advantages and disadvantages. The best option will frequently be a compromise, especially if variation exists in on-site operating conditions.

Table 4 Operational characteristics of traction aids under varying ground conditions.

Key: **Suitable:** most suitable option under given conditions.

Consider: may offer specific benefits but may not prove to be optimum.

Unsuitable: not recommended/no significant advantage in using.

Ground conditions	Tyres only	Wheel chains	Tracks
Dry, load-bearing ground	Non-aggressive grip will result in adequate traction and minimise effect of vibration on operator comfort. Suitable	May provide some protection to tyres in areas where hard, stony conditions could cause tyre damage through abrasion. Consider	Likely to be unnecessary unless traction is a limiting factor, and may result in unnecessary disturbance, greater fuel use due to extra weight and increased vibration. Could prolong the life of tyres in aggressive, abrasive conditions although unlikely that this factor alone would justify their use. Unsuitable
Brown earth under moderate climatic conditions	Traversable with standard tyre specification. Suitable	Operate efficiently; may be used on one pair of wheels to provide extra traction when terrain demands. Consider	Generally excessive for normal use; isolated wet patches can be tackled by other means, such as reinforcing racks with brush. Unsuitable
Soil with a high clay content under wet conditions	Tyre tread may clog with soil, reducing traction. Open tread patterns have greater ability to shed soil. In wet conditions wheel slip is likely to lead to reduced traction. Unsuitable	Can have an aggressive scouring effect on wet soils; they increase the wheel grip but not the footprint and tend to 'bite' through the ground surface until grip is achieved. Consider	Tracks designed to maximise traction act by aggressive gripping, likely to cut up wet soils. The potential to reduce ground pressure by increasing footprint area offers the greatest benefits for working wet sites. Consider
Moderate ground conditions with steep slopes	On limiting slopes wheel slip can result in tread pattern clogging with soil and losing any traction benefits. This is worse on heavy, sticky clay soils. Unsuitable	Give additional grip to the machine but to a lesser degree than using tracks. Consider	Can impart excellent traction for working safely up and down slopes towards the limit of the machine's operating ability. Specification should be suited to maximise grip rather than flotation, but caution should be applied in order to prevent damage to forest roads. Suitable
Wet soft/boggy ground	Unlikely to provide adequate traction for large-scale forest extraction machinery unless specialised operational techniques are used such as reinforcing racks (see Alternative operational methods section). Unsuitable	May improve grip and reduce wheel spin that can result in the machine becoming bogged but no significant flotation gain. Unsuitable	Some tracks with wide, broad plates are specifically designed to provide increased flotation as well as traction. Depending on severity may be used with good effect in combination with chains or with tracks on all wheels. Suitable
Snow with soft ground	Snow and soil accumulation in the tread of the tyres can result in a loss of grip. More aggressive tyre tread patterns are likely to be equally affected, while potentially causing more disturbance in the process. Unsuitable	Provide useful additional grip but due to lower flotation than tracks may disturb the ground and lead to erosion. Consider	Well suited, providing grip and flotation and preventing ground disturbance especially during thaw. Some tracks are not recommended as snow build-up and compression within the track can stress the machine bogies. Consider
Snow with hard frozen ground (unlikely to be experienced for prolonged periods in the UK)	Snow and soil accumulation in the tread of the tyres can result in a loss of grip. Unsuitable	Provide excellent traction improvements in slippery conditions. Suitable	Effects of vibration may cause operator discomfort similar to that for hard ground working. Added flotation is likely to be of significant advantage. Consider

Table 5 Advantages and disadvantages of traction aids.

Advantages	Disadvantages
Increased ability to work on slopes coupled with increased safety.	Can increase width of the machine and some aggressive characteristics can cause damage to standing trees and root systems.
Increased traction.	On hard surfaces increased vibration may have negative consequences for operator ergonomics.
Increased flotation.	Can damage forest roads if used inappropriately.
Prevent tyre wear and damage.	Potential for site disturbance if used inappropriately.
Increased manoeuvrability of the machine due to traction gain.	Poor fit can cause tyre wear and damage to the machine.
Reduced downtime as the machine will become bogged less often.	Additional weight and rolling resistance may lead to higher fuel consumption and reduced manoeuvrability.
Appropriate matching of traction aid to site can increase efficiency of movement and save fuel consumption.	Increased cost, although possible to offset this against increased useful life of tyres, for example.
Allow a single machine to operate over a wider range of operating conditions.	Require time to fit and /or remove when moving between different site types.
Many different types and specifications to meet a variety of operating conditions.	No one traction aid will be suited to every operating condition – compromise always has to be reached between traction, flotation aggressiveness, weight, ergonomics and efficiency.

INTERACTION BETWEEN TYRE AND TRACTION AID

Very aggressive tread patterns may prove incompatible with some traction aids as widely spaced lugs have reduced surface area for track plate grip and support. Traction aid and tyre compatibility should be checked with tyre suppliers prior to purchase.

To keep tyres in the best possible condition they must be used at the appropriate tyre pressure, stated by the manufacturer. This may vary with and without traction aids. Tyres should also be inspected regularly to establish whether traction aids are causing wear. Correctly fitted aids should prolong the useful life of machine tyres with no wear.

When considering the use of wheel chains on machine bogie assemblies, care must be taken to ensure sufficient clearance between bogie wheels for them to turn freely without snagging.

New bandtracks must be checked regularly as, over time, they can adjust to increase in length as they bed in. Conversely it is important that tracks are not too tight on the bogie assembly as this is liable to increase stress on both axle and hub bearings. Track tension can be varied by replacing long links with short links or removing an entire plate or plates as required. As an indicator, the centre sag at the top of the track when fitted at the correct tension should be between 40 and 70 mm; specific recommendations should be checked with the manufacturer.

ALTERNATIVE OPERATIONAL METHODS TO INCREASE TRACTION

Alternatives to using traction aids to increase flotation and/or traction include reducing the weight of the machine, substituting lighter equipment and the load (part loading), and strengthening the travelled routes.

Careful site organisation to minimise the use of low load bearing ground over the felling site will also help to reduce rutting. Technical Development Report 35/91 (Spencer, 1991) and Technical Note 11: *Protecting the environment during mechanised harvesting operations* (Murgatroyd and Saunders, 2005) provides detailed information on operational methods to maximise traction and flotation when operating over soft ground.

CONCLUSIONS

- Recent developments by manufactures have resulted in a wide range of available traction aids with varied characteristics that provide traction and flotation advantages under a diverse range of operating conditions. It is important to appreciate that gaining the best results in terms of traction and flotation during forest harvesting operations is achieved through a combination of appropriate traction aids and operating methods. Inappropriate use of traction aids can be detrimental to the site.

- With increasing emphasis on silvicultural methods such as continuous cover forestry in the UK, the necessity for regular thinning interventions will make repeated mechanised access essential. To preserve forest access in a suitable condition, care must be taken to minimise the impact of mechanised operations such as timber extraction, through, among other things, the appropriate selection of traction aids.
- Safety considerations are imperative, and traction aid requirements should be included as part of the risk assessment process during forest operations.

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