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Forest Research
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TECHNICAL DEVELOPMENT BRANCH

AN EVALUATION OF SMALL SCALE FORWARDING METHODS IN A BROADLEAF THINNING OPERATION

Summary

An evaluation of 4 methods of extracting shortwood from a broadleaved thinning operation highlighted that:

- Small purpose built mini-forwarders can be an economic alternative to the larger agricultural tractor and forwarder trailer units.
- Good planning prior to implementing a harvesting operation is essential. The forest operations checklist for planners and supervisors provides a valuable *aide-mémoire* when preparing to work on a site.
- The provision of good access is a key factor in any woodland operation. Access tracks should ideally be stoned to provide an all weather running surface.

The Alstor mini-forwarder was capable of working in this crop type and achieved an output of c 3.0 m³/hr and a unit cost of c £4.60/m³ extracting 3.0 m produce. It also had the best terrain capabilities of all the machines evaluated and made the least impact on the site. The Valmet/Moheda forwarder unit achieved a work output of 3.7 m³/hr and a unit cost of *c.* £5.00/m³ extracting 2.15 m produce.

This information is based on studies at one site only. Varying site factors could affect the comparability of outputs of the various equipment tested.

Introduction

The use of small scale harvesting equipment based around agricultural tractors as the prime mover is well established. Previous work by Technical Development Branch (TDB) has identified indicative work outputs and costs for agricultural tractor forwarding units in conifer crops Although work outputs for agricultural tractor forwarders[1] are generally much lower than for purpose built forwarders, their low capital costs make final extraction costs competitive with large scale equipment.

Plate 1

The Valmet/Farma Forwarder Unit

The UK Forestry Standard makes specific reference to using low impact systems for timber harvesting, especially in semi-natural woodland[2].

Agricultural tractor based forwarding units are often better suited for small scale harvesting operations, commonly associated with lowland woodlands, than their larger counterparts.

Small scattered working blocks, low volumes and restricted access can make the use of large forwarders inappropriate.

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1 Forestry Commission, Technical Development Branch, Technical Note TN** Agricultural Tractor Forwarders.

2 Forestry Commission (1998). The UK Forestry Standard, Note 5.

The objectives of the project were to:

- Identify outputs and costs for 3 low cost small scale agricultural forwarders in a broadleaf thinning operation.
- Comment on site management issues to maximise efficiency and minimise the impact of operations.
- Identify maximum slope limits for the equipment used in study work.

The opportunity was also taken to study an Alstor Mini-Forwarder.

Site & Crop Description

All study work took place in Barnetts Wood, Wigmore, Shropshire (Table 1). This wood forms part of a larger wooded area along a hill ridge which is divided into several ownerships. It is a semi-natural woodland site with a predominantly oak tree cover. This crop originated from stored coppice and single stem natural regeneration.

Table 1

Site Description

Species	Predominantly oak, with some lime and birch.
Age	c 80
Crop Description & Form	Single stems, many originating from stored coppice. Reasonable quality stems and well stocked. Mostly evenly balanced crowns with few wolf trees. Standing volume 265 m^{3}/ha. Thinning marked for 78 m^3/ha. Mean Top height 19.5 m. Mean timber height 8.0 m. Crop yield class 4.
Mean Thinning Tree Size (m^3)	0.21
Mean Thinning Dbh (cm)	19
Terrain	Bank sloping down to county road. Gullies create undulating form along bank. Majority of site accessible to farm forwarders with slopes up to 28%. Small part of area up to 35% slope.
Soil Type	Clay
Vegetation	Light hazel understorey with some grass and herb cover
Access	Recently upgraded access off county road and track extensions in to wood. Tracks not stoned. No formal rack layout in wood. No in-wood stacking area. Timber stacking area with lorry access 120 m along county road from this woodland block in a small quarry.

Trial Description

Four types of small scale forwarding equipment were selected for the trial:

- Moheda 11 tonne driven forwarder trailer & 2.85TL loader. Steerable draw bar. Trailer weight 2 270 kg Unit pulled by Valmet 6400 (95 hp) 4 WD tractor.
- Farma 8 tonne undriven forwarder trailer & 846 46 loader (Plate 1). Steerable draw bar. Trailer weight 1 846 kg Unit pulled by Valmet 6400 (95 hp) 4 WD tractor.
- 'Star' Wire Loader and 1 tonne undriven forwarder trailer. No steerable draw bar. Wire loader comprised 2 000 kg single drum winch with 40 m of wire rope fed out over an adjustable steel boom. Unit pulled by a Massey Fergusson 265 4 WD tractor.
- Alstor purpose built 8 wheel drive mini-forwarder (Plate 2). 16 hp engine with hydrostatic steering and hydraulic loader. 1 tonne trailer capacity. Total weight of Alstor 1 099 kg.

All the forwarding equipment was studied extracting oak shortwood from the site. The site harvesting specification was for 2.15 m shortwood logs but, because of machine design constraints, the Alstor and the Wire Loader were studied extracting 3.0 m produce. The other 2 forwarders were capable of handling both 3.0 m and 2.15 m. The Farma was studied extracting both product sizes but the Moheda was only studied with 2.15 m produce.

Plate 2

Alstor Mini-Forwarder

Terrain factors prevented the wire loader from getting timber to the official stacking area and it was unloaded in the wood. The other 3 forwarders managed to extract to the stacking area.

Study work recorded output information and operational factors such as material handling constraints, traction and ground damage were also noted.

Results

The results of studies are given in Table 2. To allow direct comparison between the different equipment the travel elements of the work outputs have been modelled on a common extraction distance of:

- In/out wood - 100 m.
- In/out road - 25 m.

Extraction costs are based on the following cost assumptions:

- Operator £8.00/hr.
- Valmet 6400 £7.70/hr.
- MF265 £4.80/hr.
- Wire loader £0.40/hr.
- Moheda trailer £2.60/hr.
- Farma trailer £1.70/hr.
- Alstor £5.60/hr.
- Chainsaw £1.50/hr.

These give operating costs per hour for the different units as follows:

- Moheda £18.30.
- Farma £17.40.
- Alstor £13.60.
- Wire Loader £13.20.

These hourly costs are calculated and make allowances for depreciation, maintenance costs, etc. Actual hire rates will vary from these figures, depending on type and age of equipment and regional differences such as the cost of labour.

Output data for felling and conversion have been included to provide information on the complete operation. Operator availability on the trial site was limited and it was only possible to study felling and conversion of 3.0 m produce. Output data for 2.15 m produce was obtained from an existing Output Guide[3].

Costs are shown for volume and also for weight, using a standard conversion factor of 0.94 m^3/green tonne.

3 Forestry Commission (1978). Techncial Development Branch,Output Guide G8, Thinning & Clearfelling Broadleaves and Converting to Bar Lengths and Sudbrook Pulpwood.

Table 2

Felling and Extraction Outputs and Costs

Item	Extraction Equipment									
	Moheda Trailer		Farma Trailer				Alstor		Wire Loader	
Produce	2.15 m		2.15 m		3.0 m		3.0 m		3.0 m	
Category	Output (m^3/shr)	Cost (£/m^3)	Output (m^3/shr)	Cost (£/m^3)	Output (m^3/shr)	Cost (£/m^3)	Output (m^3/shr)	Cost (£/m^3)	Output (m^3/shr)	Cost (£/m^3)
Fell	0.97	9.79	0.97	9.79	1.15	8.26	1.15	8.26	1.15	8.26
Extract	3.69	4.96	2.78	6.26	2.44	7.13	2.96	4.59	0.64	20.62
Total Cost (£/m^3)	14.75		16.05		15.39		12.85		28.88	
Cost (£/tonne)	13.87		15.10		14.47		12.08		27.15	

The terrain capability of all the machines was noted (Table 3). Heavy rain occurred before and during the study period which made the clay soil very wet.

A new track system had been constructed in the wood immediately before study work started. Because this new track was not stoned, the running surface quickly broke down in the wet conditions, making access awkward for the equipment. In particular, conditions on the ride were too difficult for the MF265/wire loader trailer to work safely and it was withdrawn from study after 2 loads. The timber extracted had to be unloaded beside the track for one of the other units to move on to the main stacking area.

Observable site damage occurred on the running surface of the new, unsurfaced tracks and at common access points where machinery ran on/off the track and into the wood. 'In wood' observable damage occurred where a tractor lost traction on a slope and was generally limited to a short length where this happened.

The Valmet/Moheda combination weighs 6 440 kg when empty. This unit has a driven trailer which, while greatly assisting terrain capability, also means that when traction is lost, the effect of the skid creates ground damage. This effect is increased by the relatively heavy weight of the unit and the power transferred through the drive system. By comparison the Alstor weighs only 1 099 kg.

The wet track conditions caused the machinery to pick up a lot of mud which was dropped on to the county road as the machinery travelled to and from the main stacking area. This created a risk to other road traffic which required appropriate signage and cleaning up.

Two of the units broke down during study work. On the Moheda forwarder trailer a hydraulic pipe broke on the rotator for the grab and there was a breakage at the knuckle joint of the main crane jib. The broken pipe was repaired on site but the broken jib caused the forwarder to be withdrawn from study work after only three loads. Both breakages were due to normal wear and tear rather than any excessive strain caused by handling the material on the trial site. The Farma forwarder trailer had a puncture to one of its tyres.

Table 3

Operational Comments

Machinery	Comment
Valmet & Moheda	➢ The following measurements represent the **maximum** slopes this vehicle combination operated on before loss of traction: • Downhill, loaded - 30%. • Uphill, empty - 30%. • Side slope, loaded - 8%. ➢ The heavier set up and larger load capacity helped make the units tracking marks more noticeable in the wood.
Valmet & Farma	➢ Unit lost traction on a 25% downhill section of newly formed ride. Could not reverse up a 25% slope. ➢ Restricted access within crop slowed movement across site. 'Steering' drawbar used to assist manoeuvring.
Alstor	➢ Alstor worked the site with few problems. Drove loaded up and down 25% slopes of wet clay with no slippage. Climbed a short bank of 44% unloaded. ➢ Moved easily amongst standing crop trees. ➢ Uncut coppice stools impeded access as driver was whipped by stems as the vehicle pushed through.
MF/Wire Loader	➢ Wet soil conditions greatly limited the ability of the tractor and it could not negotiate the level new ride without losing traction. ➢ Managed to negotiate a 28% slope in wood empty, but with loss of traction and 3 attempts.

Operational Considerations

Site Layout:

Unlike conifer plantations, it is not always possible to impose a permanent organised layout using thinning racks on broadleaved woodland. There is a longer thinning cycle in a broadleaved crop (10+ years) and rack ways cut during a previous operation may become overgrown by coppice and natural regeneration, making it difficult to identify them. Where thinnings have been delayed for 15 years or more, the previous racks created for the extraction equipment may not be appropriate for modern equipment.

Informal site layout causes a rack system to meander through the crop rather than take the most direct route to a stacking point.

Slower growth rates and reduced uniformity in a broadleaved crop make it more important to mark for quality, rather than a predetermined volume or stem density. This can result in lower product densities and produce scattered across the site in small piles, rather than being concentrated in larger heaps. At this study site, the dimensions of the produce and difficulty in being able to fell directionally, prevented fellers completing much hand stacking in the wood.

Even if a formal rack system is not present, it is important to identify clearly an access route through the crop. This allows the chainsaw operators to directionally fell towards the best point of access for the forwarder. This is important as the forwarder represents a relatively high hourly charge and good produce presentation will optimise outputs and keep total unit costs low.

Productivity:

Although the output data obtained during this trial comes from a limited number of studies, it does indicate what each class of machine is capable of and identify important operational criteria.

Conditions on this site demonstrated how a meandering access route and scattered product can affect output. Scattered products required increased machine movement to pick produce up.

The operator of the 2 tractor hydraulic loader forwarders, although experienced, was not familiar with either unit. It is fair to assume that outputs for these forwarders would increase as the operator became more accustomed. The other 2 units were used by their normal operators.

The Alstor mini-forwarder has the potential to extract timber to the roadside cheaper than the Valmet/Moheda forwarder unit in some conditions. Costs quoted have to be treated with some caution due to the limited number of studies. However, the capability of the small purpose built mini-forwarder was highlighted in these conditions. Although the Alstor has a c 1.0 m^3 load capacity compared to the 4.3 m^3 load of the Moheda it is far more manoeuvrable and can move more quickly through the crop. It also loses less time moving to pick up a load. Factors which would improve the performance of the Valmet/Moheda would be increased operator experience, greater product density, better in wood travelling conditions and longer extraction distances. An improvement in any of these factors could make the Valmet/Moheda the better option.

The outputs achieved by the Valmet/Farma forwarder unit were c 25% below that of the Moheda forwarder. In spite of this, the extraction unit cost is still competitive and reflects the lower capital cost of the Farma self loading trailer. The Farma unit was constrained by the wet soil conditions and the undriven trailer. Access was also restricted by closely spaced tree stems and the informal rack layout. Where access between stems became difficult, the operator made effective use of the steering drawbar to aid travel through the crop.

The MF265/Wire Loader had the lowest outputs (0.64 m^3/shr) and proved to be the most expensive extraction method studied. The wet soil conditions were a principal cause of the low output. A larger tractor could have helped improve the output recorded, which was 15% lower than that achieved in other studies in broadleaved thinnings. In conifer crops the Wire Loader has achieved outputs of between 3.0 m^3/hr and 5.0 m^3/shr.

Product presentation could have been better. It is likely that the outputs of the Wire Loader were depressed because of this fact. Produce should ideally be presented in piles raised up on bearers. This provides the operator of the Wire Loader with easy access to produce. This was not achieved by the chainsaw operators on this site. Bent and twisted produce also caused problems and time was lost adjusting the load.

The Wire Loader was not the ideal machine for this site or the system employed, which was best suited for the hydraulic loading forwarders. Much of the produce was too large for it to cope with, requiring another machine in the system. The Wire Loader is best suited to early thinnings, or mopping up crownwood after a commercial thinning, for use by the woodland owner as wood fuel. Ideally the Wire Loader should be used as an integral part of the felling operation, where the operator can use the winch to take down and haul logs into the trailer in one operation.

Site Impact:

The Alstor created no visible ground damage in the wood. The all-wheel drive capability and the lightweight of the loaded machine are significant factors in this. The other 3 tractor forwarding methods all created visible wheel marks within the wood, although they were not considered serious damage. These heavier vehicles have the ability to cause serious damage to soil structure where:

- Loss of traction causes skid marks which are quickly dug out due to the heavier weight and high power capabilities.

- Heavy traffic becomes concentrated at common access points on/off main tracks and on a limited number of tracks.

- Sensitive soils become very wet.

The new woodland track system was put in 1 week before the main trial started. This and the trial itself coincided with a period of heavy rain. The new track was not surfaced and had no time to consolidate before it received traffic. The rain made the running surface very wet, which was quickly 'churned up' by the tractors. Although the top soil was a clay, the sub soil was very firm and no serious rutting occurred. The very sticky running surface did cause traction problems, limiting all except the Alstor to slopes under 25% and eventually preventing the MF265/Wire Loader from operating effectively.

Working wet and muddy sites has the potential to cause a number of problems. The Forest and Water Guidelines[4] need to be followed rigorously to ensure the local environment is not compromised. Most problems, like the 'muddy road' issue, could be avoided if harvesting operations are suspended during periods of intensive rain. If they can't be suspended appropriate action needs to be taken.

As the study location was a private woodland, the timing of the tracks construction and harvesting operation were outside the control of TDB. Ideally any harvesting operation, no matter how small, should be planned well in advance of the actual operation. This allows possible constraints to be identified and the management options to be assessed before the final prescription is agreed.

A forest operations planning checklist has been published by Technical Development Branch[5] which provides forest managers with a search and record document to aid planning.

Access for Management Operations:

Access is often an important consideration when working in small woodlands. Because of the low value of broadleaved thinnings in their early years, this investment is often delayed. Technical Development Branch has investigated a number of track designs in small woodlands[6]. These investigations found that a stoned track could be constructed for as little as £2.00/m, especially where the woodland owner's own machinery was used. The location used in this trial had its own quarry, where the extracted timber was stacked. If the track used during this trial had been stoned, the quality of access would have been greatly improved. It is also quite likely that the amount of mud carried on to the county road could have been greatly reduced.

If stoning is not an option, serious consideration should be given to working very sensitive sites during the summer, when conditions should be drier.

Machine Transport & Security:

Tractor forwarders can be driven to/from site on public roads. The economics of doing this will be largely dependant on the distance to the site and the duration of the job. If lorry movement is required there is an inherent cost to this operation, which is 'diluted' on larger jobs. Ideally a forwarder unit should be parked up overnight in a local farmyard. Parking in the wood will increase the risk of vandalism.

The small size of the Alstor makes it easy and cheap to move around. It is easily transported on a road trailer towed by a Landrover or similar 4 x 4 vehicle. For security purposes it can be moved on a daily basis.

Machinery:

Ancillary technology such as a steerable drawbar can make a big difference to forwarding equipment. Both the Moheda and Farma trailers used in this trial had steerable drawbars and the operators made full use of them. They greatly improved the ability to manoeuvre in a restricted space. However this particular feature must be used with caution on slopes. Machine stability can be compromised as the normal centre of gravity in relation to the natural line of the vehicle is altered. An operator must be aware of this risk.

Training:

Training is essential to provide operators with a good knowledge from which to develop their skills and to ensure all aspects of health and safe operation of equipment are addressed correctly.

Conclusion

Purpose built mini-forwarders provide an economic alternative to the larger agricultural tractor forwarder models. The Alstor mini-forwarder worked well in this crop type. It achieved an output of 2.96 m^3/hr at a unit cost of £4.59/m^3 when extracting 3.0 m produce.

The Valmet/Moheda forwarder unit achieved an output of 3.69 m^3/hr and a unit cost of £4.96/m^3 extracting 2.15 m produce. Given the differences in the product sizes extracted and the limited data, these results are considered comparable with those of the Alstor on this site.

The Valmet/Farma forwarder unit achieved an output of *c*. 2.78 m^3/hr and a unit cost of £6.26/m^3 extracting 2.15 m produce.

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4 Forestry Commission(1993), Forest and Water Guidelines (3rd Edition).

5 Forestry Commission (1998). Technical Development Branch, Technical Note 15/98, Planning Forest Operations.

6 Forestry Commssion (1998). Technical Development Branch, Technical Note 27/98, Access Track Construction in Small Woodlands.

The Alstor had the best terrain capabilities of all the machines evaluated and made the least impact on the site. The Moheda lost traction on slopes of 30% and the Farma and Wire Loader could not operate safely on slopes over 25%. The wet soil conditions, encountered during the trial, greatly limited the terrain capability of the agricultural tractor forwarders. Maximum terrain capabilities still need to be established on dry soil.

Site factors would affect the descision of machine selection. Greater product density, better in wood travelling conditions with lower environmental constraints and longer travelling distances would favour the Moheda and Farma which can take larger loads.

The crop conditions did not suit the MF265/Wire Loader which was also greatly constrained by wet soil conditions. A larger tractor would have improved the unit's terrain capabilities. However, the main problem was that the timber was too large. This unit operates best in early thinnings or for 'mopping up' small diameter crownwood.

This trial highlighted the importance of good planning prior to implementing a harvesting operation. The forest operations checklist for planners and supervisors provides a valuable *aide-mémoire* for preparing to work on a site.

Good access and/or timing of extraction are key factors in any woodland operation.

Recommendations

The use of low impact forwarding systems should be considered for harvesting on sensitive sites.

Maximum terrain capabilities of agricultural tractor forwarders should be assessed on dry soil conditions.

Harvesting operations should be carefully planned well in advance of the actual works.

Access tracks should be stoned to provide an all weather running surface. Alternatively, sensitive sites should only be worked in dry weather.

Technical Development Branch

Develops, evaluates and promotes safe and efficient equipment and methods of work, maintains output information and provides advice on forest operations.

The use of the forest operations check list to provide an *aide-mémoire* and a written record of planning activity is strongly recommended.

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The aim of the MWI is:
"To expand and improve the management of woodlands in the Marches, in order to develop their economic potential and to maintain and enhance their environmental value".

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