Assessing the potential for spreading fertiliser in forests using ground-based machines

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- *The trial reported indicates that there is real potential for using ground-based machines to spread fertiliser in checked forest stands.*
- *The machine used in the trial was capable of travelling on soils with low bearing capacity with no observable impact on water quality.*
- *The machine was very effective in young crops with open canopies.*
- *In older pre-thicket crops, it was necessary to fell to waste one line of trees in seven in order for the machine to access the site. This is a major cost that is difficult to recommend.*
- *While the machine tested showed potential, it will not be suitable for all the site types likely to be encountered and this is a significant factor limiting its use.*
- *It is physically possible and financially attractive to apply fertiliser to checked forest stands using a ground-based machine, if a sufficient growth response occurs.*
- *Ground-based machines as alternatives to helicopters have potential but more work is required to identify a machine that suits the full range sites likely to be encountered.*

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Background

Most forest stands can reach maturity with little or no fertiliser. In the past, standard practice was to apply between 250 and 350 kg of N and/or P fertiliser to all establishing crops to ensure they could grow to closed canopy. Once the canopy closes, natural recycling of nutrients sustains the crop and there is usually no need for supplementary fertiliser applications.

In recent years there has been a move towards targeted fertiliser application with stands receiving fertiliser only when required to close canopy. These stands typically have a low Yield Class (YC) potential of less than 16 and are prone to growth stagnation if they are not fertilised. In these stands, one or more fertiliser applications is usually required to prevent the crop from going into check and to allow closed canopy to develop.

Spreading fertiliser in young forest stands is a costly operation and in order to be cost effective the preferred method is to broadcast fertiliser over large areas using a helicopter. However, concerns about the impacts of this method of application on water quality were raised and as a consequence no helicopter fertilising has occurred in recent years. Should this continue, it is expected that large areas of forest will not close canopy and will effectively fail to provide any meaningful timber resource. Within this context, the COFORD-funded GROWCHECK trial was initiated to establish the feasibility of a ground-based alternative to spreading fertiliser in these stands.

Coillte owns approximately 6,000 ha of checked Sitka spruce plantations in Galway and Mayo that require fertiliser to get them to close canopy (Carey 2005). These plantations are deficient in both P and N and occur mostly on peatlands. In order to bring these crops to maturity it is expected that an average of two fertiliser applications will be required for most stands.

Based on research from the 1980s checked stands will usually respond to fertiliser applications, assuming that poor drainage and exposure are not limiting factors. Analysis by Carey suggests that spreading fertiliser by helicopter is cost effective when it covers large areas. However, in recent years this option has not been used and it is likely that such applications may not be permitted in the future. In the interest of ensuring that existing plantations can reach their full timber potential, there is a need to explore alternatives to helicopter fertiliser applications. Ground-based machines may be the only alternative and the trial reported in this note was initiated with the view to exploring their potential.

Trial description

The potential of using a ground-based machine to apply fertiliser in a checked stand was demonstrated in a two-day machine trial conducted in Sheskin Forest, Co Mayo in October 2008. The trial took place at a time of year when growth responses from fertiliser application would not occur, so this was primarily a machine trial, i.e. growth responses were not evaluated. The trial was conducted in a typical checked stand of Sitka spruce on peatland soil in the west of Ireland.

An 'Amazone' agricultural fertiliser spreader (supplied by Farmhand www.amazone.co.uk) was fitted to a Loglogic Softrac all-terrain muskeg base machine (www.loglogic.co.uk/softrac). Alterations had to be made to the muskeg to attach the fertiliser spreader (provided by Ballina Engineering Works). On the days of the trial, a GPS guidance system was supplied by GPS Ireland. All required modifications to the spreader and GPS were made by the fitters provided by Farmhand and by GPS Ireland. All other sampling and observations were conducted by Coillte.

The objective of the trial was to explore the practicality, feasibility and cost of applying fertiliser using ground-based machines in checked forest stands, and to:

- Determine if the machine tested can travel on soils with a low bearing capacity;
- Monitor impacts on water quality;
- Quantify the effective spread of the fertiliser;
- Evaluate the potential of a basic GPS guidance system;
- Visually appraise the operation;
- Test the effectiveness of the 'limiter' function on the spreader;
- Provide a cost analysis.

Ability to travel on soils with low bearing capacity

The ability of the machine to traverse soils with low bearing capacity was determined by visual observation. For health and safety reasons, this was initially assessed using the base machine only. A trial run was conducted where the machine travelled the site in advance of attaching the spreader. The spreader was then attached and visual assessments were made during the trial. The ground pressure of the machine was calculated and this was compared to other values for typical forwarding machines modified for operating on soils of low bearing capacity.

The machine and spreader encountered no difficulty when traversing the site. The light-weight base machine and large tracks ensured that the overall weight was kept to a minimum and the ground contact maximized, resulting in a very low nominal ground pressure of 12 kPa. This compares favourably with typical forwarding machines currently modified for use on peatland forestry and clearly indicates the suitability of this machine to travel on soils of low bearing capacity.

As expected, the light-weight tracked machine with the spreader attached had a very low ground pressure and was able to traverse the low bearing capacity site. Even when loaded, its nominal ground pressure (16.5 kPa) was between 2.5 to 4.0 times lower than typical forwarder machines (42 and 63 kPa) used in the west of Ireland. However, one potential limitation of the machine was the effective ground clearance. While this caused no difficulties during the trial, it was observed that when the machine was loaded, its effective ground clearance was reduced. This potential limiting factor merits further investigation.

Impacts on water quality

Water samples were taken before, during and after the machine trial and analysed in the Coillte laboratory. The samples were monitored for suspended sediment and nutrients. Three sample points were located on a watercourse that originated in the treated area and drained into a tributary of the Oweniny River. Water sampling was conducted more than a month prior to the trial, on the day of the trial and one month after the trial.

There was no measurable impact on water quality as a result of this trial. This was mainly due to the absence of flowing


Spreader
Hopper were fertiliser is loaded. Hopper contents fully covered and protected from the elements
Limiter device mounted on left hand side only
Mounting attachment between spreader and base machine
"Softrac" base machine


AMAZONE
Hopper where granulated fertiliser is loaded. Hopper contents are fully covered from the elements. Fertiliser drops by gravity to the spinning disc below.
Limitor device is inactivated by raising it to shown position. It is raised and lowered hydraulically.
Spinning discs "throw out" the fertiliser. Rate of speed of discs determines swath distance. In the trial, the disc speed was linked to engine revs but can be modified to be linked to track speed.
Mounting attachment between spreader and base machine. This added to overall machine weight.
Note that hydraulic pipes are exposed and these will need to be better protected.
Effective clearance reduced due to extra weight.

water in the test site. The results of the water monitoring at Sheskin Property indicated water quality of a high standard in the sampled watercourse. In particular, nutrients such as ammonia, nitrate and phosphorus (measured both in the soluble ortho-phosphate and total phosphorus form) were either not detected or detected at trace concentrations in all three samplings. Furthermore, no significant difference in the results was obtained between the sample locations. A marginal improvement in phosphorus concentrations noted in the post fertilisation sampling in comparison to that observed prior to the commencement of operations was ascribed to increased flow conditions at the former sampling. No observable impact on water quality was detected arising from the trial of the experimental fertiliser spreader at Sheskin.

Effective spread of fertiliser

The rate of spread was evaluated using a control sample and random sampling.

The control sample was conducted by Farmhand using their custom supplied trays. A total of 8 trays were used, each measuring 49 x 49 cm with a plastic grid insert to collect the spread fertiliser. These were set out on the ground and the spreader made two passes using a 20 m swath. The fertiliser in each tray was then collected into one sample and analysed in the Coillte laboratory. The total weight was used to determine the spread rate of the spreader.

The random sample was set out in the identified test area and a total of 32 points were identified randomly and marked with stakes. Each stake was numbered and its GPS co-ordinates taken. A collecting tray was placed at each stake and numbered to correspond to the number on the stake. The collecting trays were provided by Coillte. The fertiliser was spread by the operator using a 20 m swath. The GPS guidance was used to ensure that parallel tracks of 20 m were driven to give an even application rate. Once completed, the contents of each tray were placed in plastic bags, identified using the number of the tray/stake and sent for analysis in the Coillte laboratory. The weight of each sample was used to determine the spread rate of the spreader.

The results of the control test show that the rate of spread was estimated at 99 kg/ha. The results from the random sampling show that the rate of spread ranges from between 2 to 94 kg/ha, with an overall average of 27 kg/ha. These exceptionally low rates were attributed to unsuitable collection trays which under-represented the actual spread. To adjust for this it was decided to apply a correction factor to the spread rates. This correction factor was calculated as:

Correction factor = Control test spread rate/Random test average spread rate = 99 kg/ha)/27 kg/ha = 3.66

Using this correction factor, the spread rates were recalculated to give the adjusted rates. These adjusted rates were then used to determine the variation around the 99 kg/ha rate of spread determined in the control test. The results suggest that while 100% of the fertiliser was spread over all the plots, the extent of variation was wide, ranging from spreading only 9% to over spreading by 349% of the required amount.

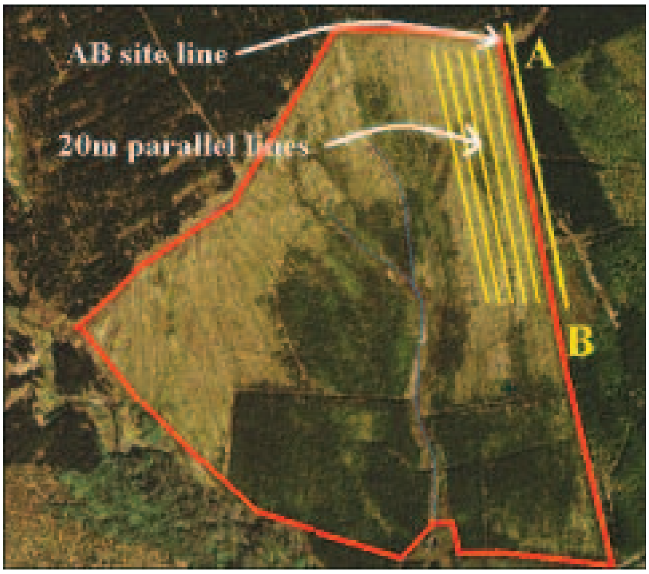
The results from this evaluation must be viewed with extreme caution, due to the low number of samples taken, the difficulties associated with setting up a 'one-off' custom made machine, and the unavailability of appropriate collecting trays for sampling. The estimated values of , 99 kg/ha for the control plot and 27 kg/ha for the random plot, were well below the required level of 250 kg/ha. In the control plot, where properly designed collecting trays were used, the discrepancy was most likely due to the machine being calibrated to spread 99 kg/ha, instead of the required rate of 250 kg/ha.

In the random plot, the lower spread rate of 27 kg/ha was probably due to a combination of incorrect machine calibration and unsuitable collecting trays. These collecting trays were not custom designed and as a result were not capable of catching all the fertiliser spread. This was observed on the ground where the fertiliser was seen to 'bounce off' the trays. To allow for this, the correction factor of 3.66 mentioned above was applied and an analysis then carried out on the variation of the spread rates. Analysis indicated a wide range of variation in the plots, which ranged between 8.6 kg/ha (9%) and 345.7 kg/ha (349%). Assuming the machine is properly calibrated to spread 250 kg/ha, this variable spread rate would be unacceptable and result in the over and under fertilization of an estimated 22.5 and 872.5 kg/ha. Consequently, this observed variation will require further analysis.

Evaluation of the potential of a basic GPS guidance system

A Trimble AG 132 Parallel Swarthy GPS system was fitted to the machine by GPS Ireland. This is a basic straight line guidance GPS system, designed mainly for agricultural use, to ensure that the machine follows parallel lines to a preset straight line. In setting up the GPS it was necessary to preset one 'fixed' straight line, known as the 'AB' line. In this trial the rideline on the west boundary was preset as the 'AB' straight line. Once set, the GPS guided the operator to travel along lines parallel to this 'AB' straight line at intervals of 20 m.

The machine operator evaluated the GPS guidance and found it to be simple to use and practical. While it did assist the operator in knowing where to travel in order to ensure that all the site was fertilised, it was not sophisticated enough to identify watercourses. This is a major disadvantage of this system, as the protection of watercourses is reliant on them being marked visually on the ground which may not be practical if adopted on a large scale. Consequently, a variable rate controller GPS model maybe more suitable and it is recommended that such a system be evaluated. Such a GPS unit is more sophisticated as it can recognise preset data such as watercourses and can automatically communicate with the spreader/operator to stop spreading fertiliser near these or other identified areas.



Visually appraise the operation

During the trial all visual appraisals were noted and particular attention was given to ingress of spread fertiliser in the pre-thicket crop and damage to residual trees.

To facilitate machine access into the pre-thicket crop, one line in seven was felled to waste and the adjoining two lines of trees on either side of this felled line were brashed. The ability of the fertiliser to penetrate into the pre-thicket crop was assessed visually by walking between the lines while the spreader operated from a stationary position on the felled to waste line.

The extent of ingress of fertiliser into the pre-thicket crop was found to be 100% (or 10 m) and 60% (or 6 m) for the open canopy and pre-thicket crop respectively. Observations for tree damage revealed that damage occurred in both open and pre-thicket crops. In the open canopy the tree damage was insignificant and where it did occur it was confined to only a small number of larger trees, which were traversed for access purposes. However, in the pre-thicket crop tree damage was more pronounced and resulted in tree wounding by the machine as it squeezed its way up through the line.

Ingress of spread fertiliser in the pre-thicket crop

Open canopy crop

- The spreader was most effective in open-canopy crops, where there were no trees restricting machine mobility.
- The machine was not capable of driving over trees that were over 2 m in height as these were too rigid.
- Deep drains of 1 m were easily traversed by the machine.
- The effective clearance was reduced when loaded but this presented no difficulties on site.
- As expected, the best spread occurred in open areas where there were no obstacles.
- The speed of application was impressive. An area of approximately 0.5 ha was spread in 20 minutes, suggesting a large ground coverage potential.

Spreading scenarios

Open canopy (left):

- Machine crossed over trees with no difficulty.
- Trees "popped" back up once driven over.
- Very effective in an open canopy situation.
- GPS guidance very effective in an "open sky" situation.
- No difficulty was observed in traversing the site.

Pre-thicket (right):

- One line removed and both lines brashed
- Machine travelled over brash with some difficulty, when half loaded.
- Fertiliser ingress to 7 to 11 m depending on branchiness of trees.
- Speed of discs could be increased to maximise ingress of fertiliser into wood.

Pre-thicket crop

- The machine was not capable of driving through areas where the crop was nearing closed canopy. In these areas felling of lines to waste was required for machine access and brashing was required to allow ingress of fertiliser into the crop.
- To allow access, a 1 in 7 line fell to waste regime is required for all pre-thicket applications.
- Manual felling to waste and brashing is labour intensive and would not be practical on a large scale.
- Felling to waste should be away from the direction of travel of the machine and involve cross cutting of the stem. The machine could not travel up one of the brashed lines due to two factors: a) the felled trees on the brashed line were felled facing the machine and the tops tended to clog the undercarriage of the machine, and b) the trees were felled to waste with no cross cutting of the stem. In contrast, the machine could travel lines where the trees were felled away from the machine and crosscut.
- High stumps presented no difficulty and this was mainly due to the presence of brash. However, stumps of 1 foot or higher were observed to cause difficulties.

Damage to residual trees

- The machine was capable of driving over trees that were less than 2 m in height. Minimal bark damage was observed and all trees reverted to an upright position once traversed.
- The base machine had an effective width of 2.1 m, which increased to 2.3 m when the spreader was attached and this resulted in some damage to adjoining trees as the machine travelled up the line.

Examples of tree wounding in pre-thicket crops.

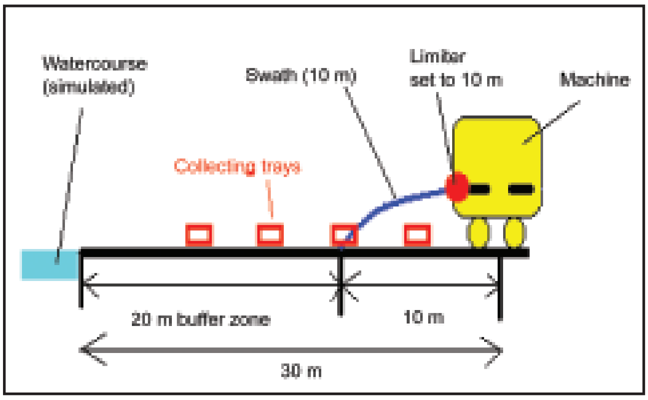
Evaluation of the 'limiter' function

The 'limiter' function refers to the ability of the machine to restrict fertiliser application on one side of the machine to prevent fertiliser entering watercourses. A typical forestry situation was simulated where the limiter could be used to spread 10 m adjacent to a 20 m buffer zone where no fertiliser is spread. This was achieved by selecting a predetermined route for the spreader, setting the limiter function to 10 m and placing collecting trays at intervals of 5, 10, 15 and 20 m from the spreader. Two Farmhand collecting trays were set out at each interval of 5, 10, 15 and 20 m respectively. The fertiliser captured at each interval was bagged individually and sent for analysis in the Coillte laboratory. The weight of each sample at each interval was used to determine the effectiveness of the limiter function.

The results from the evaluation of the 'limiter' function show that the rate of spread is significantly reduced once the 10 m swath is exceeded, but that some spread did occur beyond this 10 m for up to a distance of 15 m. No fertiliser was found to be spread 20 m from the spreader.

Analysis indicated that the limiter was effective with a margin of error of ± 5 m. Spreading of fertiliser occurred beyond the 10 m limit due to the uneven terrain which tilted the machine upwards on the side of the machine with the limiter, resulting in a higher projecting angle of spread and consequently a greater spreading distance occurred. Similarly, uneven terrain can also tilt the machine downwards on the side of the machine with the limiter, and in this case a lower projecting angle of spread would occur, resulting in a lower spreading distance.

These results indicate that a margin of error of ± 5 m should be assumed when using the limiter function. A disadvantage of this system is that it must be set manually, requiring the operator to stop the machine and lower the limiter device.



Owing to the many streams on any given site this could prove to be a nuisance unless it could be automated and operated from the cab.

Cost analysis

A detailed cost analysis was conducted for the Sheskin site using Net Present Value (NPV) to ascertain the benefit or otherwise of fertilising these areas. The analysis was conducted using a custom made model, with typical costs and revenues for Sitka spruce crops. The main assumptions of the model included:

- All costs, prices and associated assumptions are based on a report '*Western Peatlands Economic Analysis Considerations'* by Henry Phillips (2008), commissioned as part of the Western Peatland Project;
- Up to three fertiliser applications were considered to occur at 7 year intervals: the first fertiliser application rate to occur in an open canopy situation; the second fertiliser application to occur 7 years later at pre-thicket stage. The costs of felling to waste and brashing are included at this stage; the third fertiliser application to occur 7 years after the second, where it is assumed a third application is required to get the crop to close canopy;
- A stability rating of S21 is assumed (i.e. crop capable of growing to a top height of 21 m);
- A no thinning regime was assumed;
- The cost of applying the fertiliser was estimated at €295/ha; the costs of felling to waste and brashing was €200/ha;
- The actual rotation length excluded the years the crop was in check.

The cost analysis showed that a positive financial return can be expected as a result of successful fertiliser application, Despite the large costs of felling to waste and brashing assumed in the model, it is evident that positive financial returns can be achieved if the crop can be taken out of check. If only two applications are required the operation is cost effective when only a YC of 10 is achieved following fertilising. However, if three applications are required, a YC of at least 12 is required before a positive financial return can be obtained. This analysis assumes that manual felling to waste and brashing is to occur in 1 out of 7 lines. If large scale fertilising were to occur it is likely that this operation could be mechanised, possibly reducing the overall cost of fertilising. Subject to further analysis, a resulting YC of 10 may also be sufficient to return a positive financial return if three applications are required.

Conclusions

Spreading fertiliser using a ground-based machine is technically possible but more work will be needed to adapt the machine used in this trial if it is to be effective. Adaptations include investigating the possibility of using a machine with a smaller effective width, ensuring calibration of spreader is correct, further investigation into the rate and variation of the spread rate of the fertiliser, improvements to the limiter function and the use of more sophisticated GPS guidance systems. Of these, the most critical from a cost perspective is the effective width of the machine. The majority of areas in check will, at some point, require fertiliser when the crop is at pre-thicket stage. For access reasons, the adoption of the machine used in this trial requires 1 line in 7 to be felled to waste, with brashing along the adjoining line of trees to facilitate fertiliser ingress into the forest. This manual element has a significant cost implication on the overall financial viability and it is recommended that further investigation on machines with smaller effective widths be evaluated. Such machines may not require felling to waste and as a result may provide large costs savings. Alternatively, substitution of manual costs for felling to waste with mechanised costs could be considered as a means to reduce these costs. However, even when these high costs are included, analysis suggests that it is financially viable to fertilise these areas, based on current costs and revenues, if they can be taken out of check to a suitably high yield class.

The rate of spread and variation in the spread rate will need to be re-evaluated using correct sampling equipment and this should not be a major problem once the machine is properly calibrated. The limiter function was found to be effective to ±5 m, and this would be suitable for use along buffer zones. However, the deployment of this limiter function would be better utilised if combined with a more sophisticated GPS system than that used in this trial. A system like a variable rate controller GPS model would automatically identify all areas where fertiliser cannot be spread (such as in watercourses and their buffer zones). With these improvements, the use of a ground-based machine to spread fertiliser in checked forest stands has potential but further investigation will be required.

Recommendations

- Investigate the use of machines with a smaller effective width.
- Investigate calibration and effective spread rates using suitable sampling trays.
- An up to date inventory is needed to give a clear picture of what needs to be fertilised and what can be fertilised in terms of restrictions, focussing primarily on sites with a potential of reaching a YC of 12 or greater.
- Alternative management objectives need to be put in place for those sites that do not have the potential of reaching a YC of 12 or sites with environmental constraints. An accurate cost benefit analysis of fertilisation could make a good case for this to be rolled out on a large scale.
- A tumble bar modification fitted to the front of the machine would minimise damage to traversed trees and a belly plate reduce the threat of brash damaging the hydraulic pipes under the machine.

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