# Soil Scarification Equipment Mounted on a Grapple Loader

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A new small-scale equipment for soil scarification has been evaluated. The attachment consists of two pipes with harrow pins that are bolted onto a conventional log grapple. The soil scarification is done by opening the grapple, placing it to the ground, closing it, lifting and dropping the vegetation and humus layer beside the patch. A simple attachment for mechanical sowing was also tested.

Time consumption (effective time) per patch was 11.4 seconds. Time consumption was about 2.5 seconds higher per patch when also sowing was done. Nearly 90 % of the time was manoeuvring the grapple loader. Productivity was 320 patches per hour when only soil scarification was done and 262 patches per hour when also sowing was done. The average size of the patches was about 70 dm². The thin harrow pins loosened the upper layer of the mineral soil. The equipment was relatively insensitive to stones and stumps because of the driver's possibilities to place the patches on good locations, and the elasticity in the pins. The patches consisted mostly of mineral soil mixed with some remaining humus. Very little mineral soil was removed from the patch.

**Key words:** farm tractor, grapple loader, scarifier, site preparation, soil preparation, soil scarification

## Introduction

The idea of what is good soil scarification has varied over time. There are also important differences considering type of the soil and vegetation, geographical location, and if the land is meant for sowing or planting. Gemmel and Örlander (1989) say that soil scarification should give (in good concordance with von der Gönna (1990)):

- less competition (water, nutrition, light)
- increased soil temperature
- optimum soil humidity
- good growing conditions for roots (loose soil and access of oxygen)

The objectives of site preparation can according to von der Gönna (1990) be summarised as follows (and may achieve some other benefits):

- create sufficient numbers of suitable, well-spaced growing sites for seedlings, either planted or natural, to survive and attain good growth
- do so without causing detrimental or excessive soil disturbance
- obtain the desired result at the lowest possible cost

Soil scarification is often used under shelter wood and seed trees to improve conditions for natural regeneration (Karlsson and Örlander 2000). In environmentally influenced forestry of today, regeneration areas are often relatively small with irregular shape and with lots of seed trees. However, available scarification technology has been developed for large-scale clear-cut regimes, not for shelter wood conditions. Large-scale technology also leads to substantially increased costs on small regeneration areas (Frohm 1989). The technology used for shelter wood and seed tree-conditions gives as a result mounds, patches or continuos strings of the soil. The devices are large and are mounted on forwarders. Large scale scarifying technology is very efficient on larger clear-cutting areas.

Large scale scarifying technology often causes damage on the roots of the seed trees (Fjeld 1994), leading to an increased risk for wind throws and growth losses. The risk of wind throw was also pointed out as one of the main arguments against the use of shelter wood and seed-tree stands (Hannerz and Gemmel 1994). If spruce (*Picea abies*) is used as shelter wood trees the risk for root rot is obvious. Conventional soil scarification is also often considered as being too aggressive. At the same time have been reported high levels of whole-body vibrations by e.g. Golsse (1989).

This indicates a need for simple and cheap equipment for soil scarification, which suits the conditions in the environmentally adapted forestry of today. Other desired qualities are e.g. good terrain mobility, improved reach for difficult areas/spots, and low levels of whole-body vibrations.

The conventional grapple loader has since long been used, sometimes with a bucket attached to the grapple, for soil-scarification purposes. The scarified spots are then relatively small which is considered to be a problem for natural regeneration. The digging device often makes a hole, which is negative on many sites where small plants might drown in the water-filled holes. The rigid construction, as for other conventional equipment, makes it sensitive to stones or other obstacles. One advantage using the crane for soil scarification purposes is that driving is reduced substantially. Driving can also be done where the terrain is easiest, making such a system very flexible considering the choice of soil scarification spot. Many forest owners in the Nordic countries already have grapple loaders connected to farm tractors or old forwarders that creates opportunities for self-employment in soil scarification if it can be used. Berg and Wickström (1979) tested different crane-mounted (forwarder and backhoe loader) soil scarifying devices in difficult terrain. They found the technical result acceptable, and the tested method probably being less expensive than "conventional" soil scarifying under the tested conditions. Moberg (1992) tested another crane-mounted device (prototype).

A new soil scarification attachment consisting of two pipes with spring harrow pins bolted onto the grapple has been developed and studied. The soil scarification is done by opening the grapple, placing it to the ground, closing it, lifting and dropping the vegetation and humus layer beside the patch. The hypothesis that the forest owners with this technology can get a soil scarification technique, which is adapted to the conditions discussed above e.g. small objects, shelter-woods and environmental restrictions was followed up by a study with the objective to investigate the new attachment.

## Material and methods

### *Equipment*

The device was mounted on a conventional grapple loader and consists of two metal pipes with harrow pins bolted onto the grapple (Fig. 1). The number of harrow pins can easily be varied. In the studies 7 pins (4 on one side + 3 on the other side) and 11 pins (6 + 5) were used. The distance between the endpins was 80 - 90 cm and the maximum opening width was about 120 cm. A simple attachment for mechanical sowing was also developed and tested. It consists of a conventional seed flack which was mounted on a rigid plastic pipe about 1 m out from the grapple and manoeuvred by a string inside the pipe so that it automatically sows when the grapple is opened and releasing the turf beside the patch.

**Figure 1.** Studied equipmént for soil scarification and sowing mounted on a grapple

The base machine was the 4-wheel drive farm tractor Valmet 705 modified for forestry use (Table 1). The crane was the FMV 290, which was mounted on the tractor when driving without the trailer, and on the trailer when driving with the trailer. The trailer had a ballast of 1700 kg for improved stability during crane work. The stakes on the trailer were also removed to make crane movements easier across the trailer.

**Table 1.** The base machine and the trailer

| The tractor, Valmet 705/4 (modified for forestry) | |
|---|---|
| Enginepower | 61 kW |
| Pump capacity | 46 dm$^3$/min |
| Oilpressure | 17 Mpa |
| Wheels | 13.6-24/6 (front)<br>18.4-34/8 (rear) |
| Mass | 1850 kg (front axle)<br>3300 kg (rear axle) |
| **The trailer, FMV 290 with 3-wheel bogie and a crane with a grapple** | |
| Mass incl. the crane and grapple | 2950 kg |
| Maximum load | 8 tonnes |
| Crane reach | 6.15 m |
| Lift. cap. on full reach | 3000 N |
| Grapple | Area 0.18 m$^2$<br>Opening width 100 cm |
| Operating levers | 6 levers with extension |

### *Work method*

The work method consists of driving trails at 13 m distance and about 7 m between work places. About 18 patches within crane reach are made on every work place, giving about 2000 patches per hectare (Fig. 2).

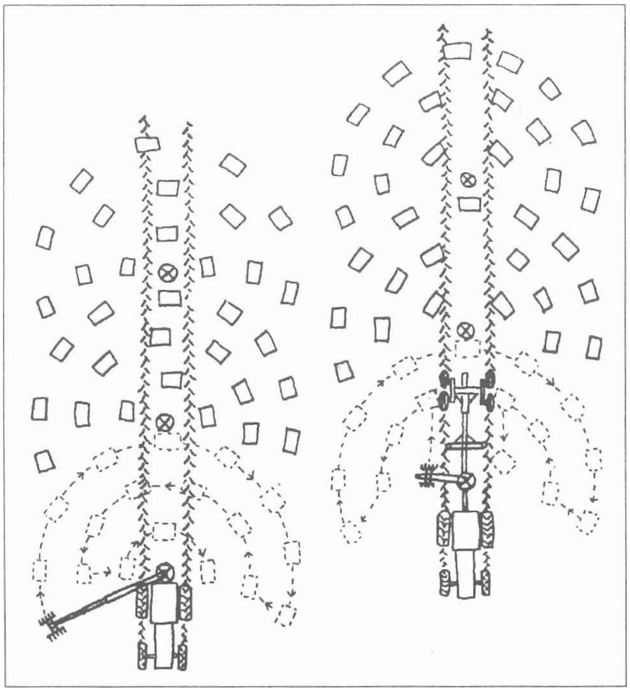

**Figure 2.** "Ideal" working scheme without and with trailer

*The study*

The study was carried out on two regenerating areas with seed trees (Table 2). The areas were cut about 1.5 years earlier. In the study time and the technical result were measured. Terrain classes were measured according to Terrain classification system (1991). The number of harrow pins was varied from 7 to 11 on both areas, and the two types were studied in combination with:

- tractor mounted crane
- tractor mounted crane + sowing
- trailer mounted crane
- trailer mounted crane + sowing

## Results

*Productivity*

An average of about 18 patches per work place was achieved (Table 3). At a higher density of patches pieces of turf and harvesting residues often covered patches made earlier. The freedom to choose scarifying spots decreases also with an increasing number of scarifying patches.

Time consumption for the scarifying element was close to 90 % of total effective time. Time consumption was highest when sowing. Difference in time consumption when scarifying with the crane mounted on the tractor and when scarifying with the crane mounted on the trailer seemed to be very little. However, a different number of patches per work place make a comparison difficult. Time consumption per patch is shown in Table 4. Sowing increased time consumption with 2.5 seconds.

Variance analysis of time consumption (effective time) per work place was done with the variables area, trailer, sowing and number of patches respectively. The analysis showed no significant difference between the areas, but the other variables were significant (Table 5). An analysis of time consumption for only the ele-

**Table 2.** The studied areas

| | *Area A* | *Area B* |
|---|---|---|
| Cutting method | Grapple harv. + forwarder | Grapple harv. + forwarder + chipping logging residues |
| Seed treas per ha | Approx. 140 | Approx. 80 |
| Bearing capacity* | 2 | 2 |
| Roughness* | 2 (97 % of the area) | 1 (4 % of the area) |
| | 3 (3 %) | 2 (51 %) |
| | | 3 (42 %) |
| | | 4 (4 %) |
| Inclination* | | 1 (96 %) |
| | | 2 (4 %) |
| Scarification resistance of soil surface* | 3 | 2 (67 %) |
| | | 3 (33 %) |
| Ratio of stones* | 5 | 5 |
| Logging slash and stumps* | 2 (87 %) | 1 (94 %) |
| | 3 (3 %) | 2 (4 %) |
| | 4 (8 %) | 4 (2 %) |
| | 5 (2 %) | |
| Soil type | Sandy till | Sandy till |
| Vegetation type** | Dwarf shrubs (87 %) | Dwarf shrubs (18 %) |
| | Grass (13 %) | Grass (82 %) |

* according to Terrain classification system, (1991)
** according to Hägglund & Lundmark, (1984)

**Table 3.** Measured averages per work place

| | *Area A* | | | | *Area B* | | | |
|---|---|---|---|---|---|---|---|---|
| | Tractor mount | Tractor mount + sowing | Trailer mount | Trailer mount + sowing | Trailer mount | Trailer mount + sowing | Trailer mount | Trailer mount + sowing |
| No. of patches | 18.6 | 18.1 | 18.8 | 19.0 | 19.1 | 18.7 | 17.3 | 16.8 |
| Moving dist., m | 7.9 | 7.6 | 7.0 | 7.6 | 7.9 | 7.7 | 7.2 | 7.1 |
| No. of patches/ha | 1850 | 1845 | 2073 | 1940 | 1873 | 1884 | 1869 | 1846 |
| No. of seed trees | 1.9 | 1.4 | 1.5 | 1.1 | 0.7 | 0.9 | 0.7 | 1.4 |
| No. of small trees | 0 | 0 | 0.1 | 1.2 | 0 | 0.1 | 0 | 0 |
| No. of repeats | 0 | 0 | 0 | 0 | 0.2 | 0.4 | 0.1 | 0 |
| Time cons., sec. | | | | | | | | |
| Driving | 17.2 | 16.9 | 13.6 | 15.9 | 18.2 | 16.8 | 16.2 | 17.1 |
| Meas. before sc. | 6.0 | 6.3 | 6.4 | 6.5 | 6.5 | 6.0 | 5.9 | 6.1 |
| Scarification | 184.1 | 224.4 | 175.9 | 222.5 | 187.1 | 231.7 | 169.5 | 204.4 |
| Measures after sc. | 5.3 | 5.4 | 6.1 | 5.6 | 6.2 | 5.8 | 5.5 | 4.9 |
| Cleaning device | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 |
| Other time | 0.4 | 0 | 0 | 1.5 | 0 | 0 | 5.0 | 0 |
| Total time | 213.0 | 253.0 | 201.9 | 251.9 | 218.1 | 260.3 | 202.2 | 232.5 |

**Table 4.** Measured time per scarified patch

| | Scarif., sec. | Total time, sec |
|---|---|---|
| *Area A* | | |
| Tractor mount | 9.89 | 11.44 |
| Tractor mount + sowing | 12.42 | 14.00 |
| Trailer mount | 9.36 | 10.75 |
| Trailer mount + sowing | 11.71 | 13.26 |
| *Area B* | | |
| Tractor mount | 9.81 | 11.44 |
| Tractor mount + sowing | 12.38 | 13.90 |
| Trailer mount | 9.82 | 11.71 |
| Trailer mount + sowing | 12.17 | 13.84 |

**Table 5.** Analysis of variance (GLM, type III) on total time per work place

| Source | Df | F-value | P-value | Sign. |
|---|---|---|---|---|
| Area | 1 | 2.1 | 0.148 | - |
| Trailer | 1 | 7.40 | 0.007 | ** |
| Sowing | 1 | 188.6 | <0.001 | *** |
| No patches | 1 | 110.7 | <0.001 | *** |
| Error | 152 | | | |

ment scarifying showed the same result. A test of combinations showed no significance. An analysis of the difference in time consumption per work place for different equipment and methods is shown in Table 6. All alternatives were significant.

As number of patches and mowing distance changed between alternatives was made an estimation of productivity for 111 work places and 2000 patches per ha (Table 7). Time for disturbance was excluded.

**Table 7.** Estimated productivity at 2000 patches per ha. Averages for both areas

| | Hectares per eff. hour | Patches per eff. hour |
|---|---|---|
| Tractor mount | 0.1565 | 313 |
| Tractor mount + sowing | 0.1287 | 257 |
| Trailer mount | 0.1634 | 327 |
| Trailer mount + sowing | 0.1340 | 268 |

*Technical result*

The patches were under ideal conditions a mixture of humus and mineral soil. Only the vegetation (dwarf shrubs) and a piece of humus were then lifted away and the rest of the humus was mixed with mineral soil. The mineral soil level was about the same after and before soil scarification. Only on a few occasions a large stone was lifted away.

If the vegetation was grass type it sometimes was left in the patch, lichen-type vegetation was only mixed with the mineral soil and not removed from the patch. Tree roots became often visible in the patches, and

**Table 6.** Estimated average time consumption per work place for different equipment (corrected for different number of patches using GLM LS-Means procedure)

| Alternative | Time cons., sec | P-value for difference against alternative | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| 1. Tractor mount | 215.8 | | <0.001 | 0.025 | <0.001 |
| 2. Tractor mount + sowing | 256.5 | <0.001 | | <0.001 | 0.050 |
| 3. Trailer mount | 202.0 | 0.025 | <0.001 | | <0.001 |
| 4. Trailer mount + sowing | 244.1 | <0.001 | 0.050 | <0.001 | |

thick layers of harvesting residues made it difficult for the harrow pins to reach the ground. A lot of needles were also left in the patches.

Sensitivity for stumps etc was relatively low due to the long springy pins as they slide on the obstacles. The following obstacles were found (proportion of patches):

- stumps 5 %
- stones, rocks etc. 44 %
- lots of harv. residues 16 %
- trees 6 %
- big roots 5 %
- sight problems 1 %

The average scarified patch was almost 80 dm² (Table 8), of which less than 10 dm² was covered with e.g. pieces of the removed turf, which had fallen back into the patch. More than half of the patch surface was a mixture of humus and mineral soil, where the mineral soil covered at least 25 % of the surface. Pure mineral soil did not occur. The result did not vary much between the two areas or equipment. Only "sowing" and "number of pins" had a significant effect on the uncovered patch.

The area of the patches varied between 62 dm² and 72 dm² (Table 8). The largest patches were for 11 pins and no sowing, and the smallest patches were for 7 pins and with sowing. More pins gave larger and more worked patches. With dwarf shrub vegetation 7 pins were enough to lift away the vegetation. With grass-vegetation pieces of vegetation were then left in the patches. 11 pins improved the result mainly for grass-vegetation. Sowing increased the risk for covering the patch with pieces of the turf, as the turf must be dropped close to the patch to hit the patch with the seeds.

**Table 8.** Average size of patch, dm²

| | 7 pins | 11 pins | 7 pins + sowing | 11 pins + sowing | Mean | Stand. Dev. |
|---|---|---|---|---|---|---|
| Tot scarif, non covered, area of which: | 68.0 | 72.2 | 62.3 | 64.5 | 68.4 | 22.2 |
| - pure humus | 13.7 | 11.6 | 10.7 | 8.4 | 11.3 | 13.6 |
| - mixture, <25 % min. soil | 5.6 | 5.2 | 16.5 | 2.5 | 5.6 | 13.9 |
| - mixture, >25 % min. soil | 37.0 | 43.4 | 25.7 | 38.1 | 39.0 | 30.7 |
| - rock & stone (>1dm²) | 11.6 | 12.3 | 9.4 | 15.6 | 12.7 | 13.5 |
| Scarified, covered area | 11.2 | 6.8 | 11.0 | 11.4 | 9.4 | 8.7 |

*Regression analysis*

The different variables influence for the result was analysed with regression analysis. As a measure of the result the area of mixed humus/mineral soil with at least 25 % mineral soil was used. All tested variables were dummy-variables (1 or 0). The variables showing the best explanation are shown in Table 9. No significance for "sowing" means that at least some of the differences in Table 8 depend on the varying ground conditions.

**Table 9.** Regression analysis on area humus mixed mineral soil (>25 % mineral)

| | Value, dm² | P-value | Sign. |
|---|---|---|---|
| Constant | 81.9 | <0.001 | *** |
| Block, stone, rock | -28.5 | <0.001 | *** |
| Logging residues (abundant) | -30.6 | <0.001 | *** |
| Poor sight | -51.3 | 0.105 | - |
| Grass vegetation | -13.9 | 0.006 | ** |
| 7 pins | -13.7 | 0.009 | ** |

## Discussion

The patches in the study became smaller in case of stones etc. However, sensitivity is relatively low due to the springy pins. The operator has also possibilities to use the most favourable spots. A conventional (rigid) scarifier will in many cases have to move large amounts of stones *etc.* to reach the mineral soil, and also require larger forces.

A poorer result was achieved in case of large amounts of logging residues also. The patches should be made where the amount of residues is low. Coniferous forests with dwarf shrubs seem to be one favourable soil/vegetation type for the examined technology. In a study by Scholander (1973) was also indicated that the vegetation of dwarf shrubs had much higher tear resistance than that of grass.

A shorter crane makes time consumption for moving increase. With e.g. a 4-meter crane the number of work places per ha will be doubled. Increased crane reach will make it easier to reach different places on the ground at the same time, as it will be easier to plan driving.

Based on the information given by e.g. Gemmel and Örlander (1989), Bergsten and Normark (1992), and

Solbraa & Andersen (1997) this soil scarification result can be judged as follows:

- it is good that the surface on the patches is at the same level as the initial level on the mineral soil (on cold and humid locations a mound would be preferable).
- loosening of the mineral soil and mixture with humus should give advantages for growing
- the presence of tree roots and humus could increase the risk for damage by insects compared with a patch surface with only mineral soil
- the mixture of humus/mineral soil could decrease the risk for frost-lifting of plants
- the mixture of humus/mineral soil improves access of nutrients
- the piece of turf (in the study) can probably not be used for planting due to lack of mineral soil
- the risk for leaching of nutrients and erosion should be small compared with conventional technology
- the time for grass to grow might be shorter than if more radical methods are used

The idea with this technology is that it should be simple and cheap. Due to the short time of use per year the price is of highest priority for self-employed forest owners. However, there could be reasons to develop more expensive and refined technology for professional forestry. A conventional grapple might not offer an optimal geometry for movements, but a specialised device might give other possibilities. If, for example, mowing direction for the pins is changed (opening instead of closing) mechanised sowing or planting will be easier to do as the device will be located right over the scarified patch. Another possibility could be to, more or less automatically, operate several devices on one machine.

Alcázar *et al.* (2002) found erosion after mechanical site preparation mainly where the mineral soil was exposed. This supports an assumption that the studied method (technology) from an environmental and esthetical point of view has important advantages compared with more radical scarifying methods. Erosion should not be much of a problem as mineral soil and humus are mixed.

This technology can also be used as a complement for conventional forwarder based soil scarifiers. This means where the crane can be used to reach places, which are difficult to reach with a large machine. It can also be used in forestry where sensitive soil scarification is requested for environmental, cultural, and esthetical reasons.

This technology should be studied further attached to other possible base machines. More studies should also be carried out on different vegetation/soil types including follow up of natural regeneration, sowing and planting. The distribution of seeds on the patches should be investigated further. Örlander and Nilsson (1999) found that mounding could reduce damage from pine weevil on seedlings substantially. The situation with this new type of soil scarification should be investigated also. Another important matter to investigate is if temperature in the patches during winter is at the same low level as was found by Lindström and Troeng (1995) in planting mounds.

## Conclusion

This study supports the hypothesis that the forest owners with the studied technology can get soil scarification, which is positive from many points of view, not least environmentally. Other important areas are sites especially suited for natural regeneration, small clear cuttings and when terrain conditions are too difficult for conventional pulled equipment.

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# ОБОРУДОВАНИЕ НА ГРЕЙФЕРЕ ДЛЯ ПОДГОТОВКИ ПОЧВЫ ПОД ЛЕСОПОСАДКИ

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*Резюме*

Оценивется мелкомасштабное оборудование для обработки почвы под лесопосадки. Приспособление состоит их двух труб с рессорной бороной, которые крепятся к обычному грейферу. Подготовка почвы происходит следующим образом: грейфер раскрывается, подводится к намеченному участку земли, замыкается, поднимается и переносит растительность вместе с почвой на участок рядом. Одновременно тестировалась простая насадка для механизированного посева.

Время обработки (эффективное время) одного участка 11,4 сек. Время обработки вместе с последующим посевом на 2,5 сек больше. Почти 90 % времени уходит на маневрирование краном. Продуктивность 320 участков при простой обработке и 262 участка при совместном посеве. Средний размер переносимых участков 70 дм$^2$. Узкие зубья бороны разрыхляют верхний слой минеральной почвы. Камни и пни на оборудование особенного не влияют, так как у водителя есть возможность выбрать подходящее место для переносимых участков, а также всвязи с элластичностью бороны. Обрабатываемые участки состоят часто из минерального слоя почвы частично перемешанного с перегноем. Очень небольшая часть минерального слоя переносится с обрабатываемого участка.

**Ключевые слова:** сельскохозяйственный трактор, грейфер, скарификация, подготовка участков, подготовка почвы, скарификация почвы