# WRAP AD Cultivation Trials
# Addiewell & Dalquhandy 2011

## Summary


The cultivation trials were undertaken on two different sites, Addiewell, West Lothian and Dalquhandy, Lanarkshire. The site at Addiewell was mainly comprised of rocky, stone shale which was a by product of extraction of oil from shale in the late 1800s and early 1900s. Dalquhandy was an opencast coal site reclaimed around 2000 and was mainly compacted clayey material over a boulder surface burden.

The work was carried out in January 2011 after a period of rain, snow, frost and typical winter storms. Although these were not ideal conditions, suitable measures were taken to control runoff of silt from travelling and cultivation areas.

The site was divided into 15 of 12 x 12m plots (0.0144ha) and enriched with either Compost (Com) or Anaerobic Digestate (AD). The cultivation was carried out using a Hitachi PC210LC tracked excavator fitted with a riddle type bucket.

Transportation, spreading and mixing of the compost/AD to each plot was also done using the excavator. Moving the compost to the plots by excavator was slow, and therefore not representative of operational practice, although it was the most cost-effective method in the circumstances for the small research area concerned. It was accepted that cost of moving amendment indicated by the studies would be significantly higher than the operational alternative for larger scale operations of using dumpers. However, the cultivation and mixing element of the whole operation would be broadly representative of likely operational practice.

The cultivation and mixing outputs and cost from Addiewell were **0.014 ha/shr** and cost **£5,999/ha**. At Dalquhandy these were **0.032 ha/shr** and **£2,509/ha.**

An estimate from 2009 at an adjacent trial site at Dalquhandy of the cost of loading, moving and placing compost using a 3 tonne dumper was in the region of £1,100 / ha, equating to a total operation cost of **£3,600 to £6,100** depending on site conditions and excluding the cost of organic amendment.

The excavation work at Addiewell was more difficult and took longer for the machine due to compaction and dryness of the shale material. The clayey Dalquhandy site was far easier for the machine to cultivate because of the wetness of the soil after winter weather.

The excavator was able to work and travel on and around the Addiewell site without any difficulty. However, due to the particularly wet conditions at Dalquhandy, the machine quickly 'churned up' the ground when travelling and the plots, when re-dug during the addition of the compost and AD, became too wet for the excavator to traverse.

# Introduction

This report results from data gathered during the cultivation of the Addiewell oil shale tip, West Lothian and Dalquhandy former opencast coal site in South Lanarkshire in early 2010. These were WRAP[1] funded compost and tree planting field trails. The aim of the research was to investigate the beneficial effects of complete cultivation during reclamation of mineral sites for tree planting with application of green compost and / or anaerobic digestate as organic amendment.

[1] Waste Resources Action Programme. Investigation into the benefits of incorporating anaerobic digestate, pure and mixed with compost, into brownfield land during cultivation for forestry afteruse. OBF013-006 (Addiewell) & 003 (Dalquhandy)

# Objectives

To evaluate and obtain cost and output results from time studies on trial plots of cultivation and addition of organic soil amendment for tree planting on former mineral extraction sites. The trial plots were treated with different application rates of PAS100 green compost or PAS110 anaerobic digestate (AD), or both for subsequent planting and tree growth measurement, which were reported separately[2].

# Work method

The sites at Addiewell and Dalquhandy were marked out with 15 of 12 x 12 m plots, indicating an area of 0.014 ha. Plots were separated by an uncultivated 2 m boundary to prevent nutrients moving between plots and causing adjacency effects on subsequent soil analyses and tree growth data. However, these uncultivated surrounds also slowed the rate at which rainwater drained from the plots on the clayey site at Dalquhandy, which consequently became very wet during cultivation owing to the conditions at the time. Under operational conditions cultivated outlets known as 'drainage taps' would have been installed at cultivation.

Each plot was completely cultivated using a tracked excavator to the desired specification of at least 1 m depth and were identified by permanent coloured marker posts located at each corner.

Compost from green waste, certified as BSI PAS100 standard, was obtained from West Lothian Recycling Ltd, Addiewell ('POD' 0-40 mm) and PAS110 standard AD from Scottish Water, Deerdykes, Cumbernauld. These soil amendments were spread over the surface of the trial plots at the pre-calculated volume rate and re-dug into the upper c 50 cm of spoil using the excavator. Time study data was gathered for each treatment in accordance to Technical Development (TSI) Time Study Instructions criteria.

Owing to proximity and the short duration of the trials, the distribution of Compost and AD from the roadside stock-piles to the cultivation area was undertaken by the excavator itself. This would not be efficient in operational conditions and was not studied.

[2] Hipkin, A. & Wall, M. (2013). Addiewell Project, Site Reclamation using Anaerobic Digestion 'Fibre'. WRAP
Hipkin, A. & Wall, M. (2013). Dalquhandy Project, Site Reclamation using Anaerobic Digestion 'Fibre'. WRAP

# Site description/location

The trial site at Addiewell, West Lothian was formally an oil shale mine 'bing' that had been levelled off and landscaped by machines in the mid 1980s. A shallow layer of mineral soil was laid across the surface and sown with grasses to establish a sward. Several broadleaved tree species including birch, willow and alder had been planted around the site boundary with some Scots pine and larch. The site was at an elevation of 170 m above sea level with annual rainfall in the region of 550 mm.

The trial site at Dalquhandy, Coalburn, Lanarkshire was formally an opencast coal mine at owned by Scottish Coal. The site had been restored in early 2000 to open hill grazing. The site is very exposed at an altitude of 270 m, with an average annual rainfall of 1800 mm. The prevailing wind is from the South West. However, in extreme winter conditions the wind can be from the North East with heavy snow falls.

The restored opencast 'soils' comprised compacted clayey material spread by dozer over the replaced excavation overburden, topped by a variable shallow layer of clayey mineral soil with sporadic peaty clods, and seeded to encourage natural grassy growth.

In order to prepare the ground for planting in spring 2011, the cultivation work on both sites was required in January 2011 when rain, snow and frosts were encountered.

# Machinery description/specification

All the cultivation was carried out using a Komatsu PC210 LC tracked excavator, on 70 cm flat track plates with a 9.0 m boom reach, costing £80 / hr. The machine was fitted with a riddle type bucket. The dimensions were 1.50 m (wide), 0.70 m (depth) and 1.00 m (high). The average volume of material in the bucket was 1.05 $m^3$.

The excavator was also used to transport, spread and re-dig the compost and AD into the trial plots. The following plates show the excavator cultivating one of the trial plots at Addiewell and the riddle bucket at Dalquhandy.

Plate 1. Hitachi PC210LC excavator

Plate 2. Riddle bucket

# Cultivation Method

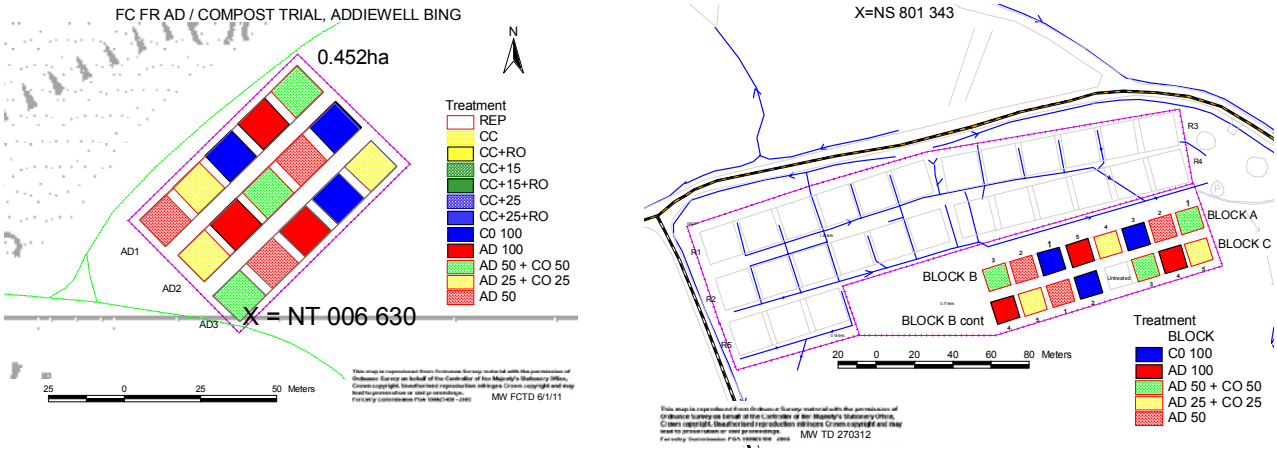
The area at each location was just under 0.50 ha, divided into 15 plots of 12 x 12 m, producing a 0.014 ha cultivated plot **(Figure 1)**. Around each plot was a 2 m uncultivated buffer to reduce the leaching from compost and AD between the plots.

Each plot was cultivated to a depth of 1 m with each bucketful of spoil dug, turned and then tilled using the bucket to mix the different soil layers through the profile, creating a loose, relatively uniform medium for planting. After the initial cultivation the ground was levelled using the bottom of the bucket.

The compost and AD were delivered by HGV and tipped c 25 m from the trial area at Addiewell and 50 m at Dalquhandy, where suitable drainage at storage dumps and filtration zones had been prepared in advance. The excavator tracked over, loaded the bucket and returned to place the amendment on the plot for be mixing in.

The excavator was also used to lift and transport the compost and AD to each plot and spread (riddle) it across the area. When the material had been spread relatively evenly, it was dug into the plot to a depth of c 50 cm and again levelled using the rear of the bucket. Coloured wooden posts were placed at the corner of each plot to identify treatments.

Figure 1. Layout of the trial plots that were the same at each location




# Results

Two plots at each site were randomly selected for time studies to determine efficiency.

The cultivation results from Addiewell, West Lothian are shown in **Tables 1 and 2**. An indication of the actual cost per hectare to cultivate, move compost / AD and mix with soil to enrich the trial plots is given in **Table 3**.

Table 1. Initial cultivation, spreading, mixing in of compost/AD and level off site

| | Move on Plot | Dig Ground | Dig in & Spread Compost / AD | Level Ground | Remove Rock | Total Time (Bm) | Total Time (Sm) | Area (ha) | Output (ha/Bhr) | Output (ha/Shr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Plot 1 COM | 9.95 19% | 16.35 32% | 8.47 16% | 16.53 32% | 0.57 1% | 51.87 | 69.19 | 0.0144 | 0.016 | 0.012 |
| Plot 2 AD | 6.89 | 17.95 | 9.68 | 8.90 | | 43.42 | 57.92 | | 0.019 | 0.015 |
| Average | 8.39 | 17.15 | 9.075 | 12.71 | 0.57 | 47.38 | 63.20 | | 0.018 | 0.0136 |

Table 2. Transport, of Compost and AD to the trial plots

| | Move to Load | Load Bucket | Move to Unload | Unload | Total Time (Bm) | Total Time (Sm) | Volume Moved ($m^3$) | Output | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | ($m^3$/Bhr) | ($m^3$/Shr) |
| Plot 1 (C) | 4.76 | 3.76 | 6.96 | 3.33 | 18.81 | 25.09 | 7.10 | 22.60 | 16.97 |
| Plot 2 (AD) | 4.67 | 2.60 | 5.91 | 4.11 | 17.29 | 23.06 | 7.90 | 27.41 | 20.55 |
| Average | 4.56 | 3.18 | 6.44 | 3.72 | 17.90 | 23.87 | 7.50 | 25.13 | 18.85 |

Table 3. Actual Addiewell cultivation costs (standard)

| Treatment | Cultivation (£/ha) | Transport (£/ha) | Total Cost (£/ha) |
|---|---|---|---|
| Compost | 6 666 | 2 321 | 8 987 |
| AD | 5 333 | 2 133 | 7 466 |
| Average | 5 999 | 2 227 | 8 226 |

The results of the time study cultivation trials at Dalguhandy, South Lanarkshire are shown in **Tables 4 and 5**.

Table 4. Initial plot cultivation, spreading, mixing in of compost/AD and levelling off

| | Move on Plot | Dig Ground | Dig in & Spread Compost / AD | Level Ground | Total Time (Bm) | Total Time (Sm) | Area (ha) | Output (ha/Bhr) | Output (ha/Shr) |
|---|---|---|---|---|---|---|---|---|---|
| Plot 1 Com | 3.11 16% | 8.56 45% | 4.54 24% | 2.88 15% | 19.09 | 25.46 | 0.0144 | 0.045 | 0.034 |
| Plot 2 AD | 4.01 | 6.78 | 6.64 | 4.02 | 21.45 | 28.61 | | 0.040 | 0.030 |
| Average | 3.56 | 7.67 | 5.59 | 3.45 | 20.27 | 27.04 | | 0.0426 | 0.032 |

Table 5. Transport of compost to the trial plot

| | Move to Load | Load Bucket | Move to Unload | Unload | Total Time (Bm) | Total Time (Sm) | Volume Moved ($m^3$) | Output | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | ($m^3$/Bhr) | ($m^3$/Shr) |
| Plot 1 | 12.51 | 13.09 | 12.55 | 3.05 | 41.20 | 54.96 | 7.10 | 10.33 | 7.75 |

An indication of the actual cost per hectare to cultivate, transport and enrich the trial plot at Dalquhandy is given in **Table 6**.

Table 6. Actual Dalquhandy cultivation costs (standard)

| Treatment | Cultivation (£/ha) | Transport (£/ha) | Total Cost (£/ha) |
|---|---|---|---|
| Compost | 2 352 | 5 085 | 7 437 |
| AD | 2 666 | | 7 751 |
| Average | 2 509 | | 7 594 |

During the field work only the transportation of the compost was studied, the locations of the AD were in the same areas as the compost. Due to time constraints it was decided to use the data gathered for both materials as it was judged that no difference in time would have been observed.

# Discussion

## Addiewell

During the original reclamation of the site at Addiewell, it had been levelled, compacted and landscaped by heavy machinery. The structure of the shale/soil was very dense, dry and the excavator had difficulty initially starting to cultivate each plot. To try and reduce this, the operator would use the bucket to mark the plot boundary by a slight indentation and pulling (screef) up the vegetative growth. Thereafter, using the screef line, the bucket dug into the material with slightly less difficulty and each bucketful was turned out, loosening and aerating the spoil as it fell.

## Dalquhandy

The original reclamation at Dalquhandy **(Plate 3)** had left much softer conditions than at Addiewell owing to its clay content. Prior to the trial work being undertaken the site had been covered for several weeks with snow and ice, which had melted and percolated into the ground making the ground wet.

The cultivation of the ground at Dalquhandy was easier for the machine and it coped well on site. The only problem encountered was during the spreading and mixing of the compost when the excavator was sitting on the previously treated area and on occasions started to sink in the soft ground. In operational conditions this would have been overcome by the machine working to one side from uncultivated ground.

Plate 3. Dalquhandy cultivation site – note steam from the warm compost

Another observation was that the cultivated plot, given the rain and conditions turned into a sump for the water. The cultivated area was loose with air pockets that permitted the water to enter and given the surrounding area still compacted it stopped the natural flow of water cross the surface and under ground. In operational planning it is crucial to ensure that water within cultivation cells can escape e.g. by means of 'drainage taps' of cultivated ground on the lower side of cells.

The compost and AD was sited c 60 m from the trial plot and the ground quickly became cut up with rutting and ponding developing. The main route in and out of the trial plot was soon unusable and alternative one adopted that seen the machine travel longer each time to move the material onto the plots.

As stated in previous reports, the 'holistic' approach to reclaiming opencast mine sites using larger machinery requires critical planning to ensure that the operations can be maintained given the conditions encountered.

## Compost and AD movement

The actual cost of movement of compost and AD to the plots, according to the time studies during the research trial preparation, was £2,227 at Addiewell, where the average movement distance was 60 m and £5,085 at Dalquhandy, where the average movement distance was 100 m each way and the site was much softer. In both cases the application rate for organic amendment was c 170 m3 / ha (c 105 tonnes of compost or 95 tonnes of AD).

For an application rate of 450 tonnes / ha, a previous estimate[3] of the cost of loading compost by 13 tonne excavator into a 3 tonne 4 wheeled Terex PT5000 dump truck and moving it an average distance of 250 m for placement was **c. £1,100**. However, this study also related to smaller scale, non-operational conditions of research trial preparation so are considered high.

# Conclusions

The reclamation sites were different in composition: Addiewell was predominately red and black shale that had been levelled and topped off with a shallow layer of mineral soil. Dalquhandy was a restored opencast site having little original soil material. The 'soil' profile comprised compacted layers of clay-rich soil forming material over a boulder over-burden, topped off with a shallow mineral layer.

The machinery coped reasonably well cultivating each site. The Addiewell site was harder for the machine to dig into the soil due to the hard compaction and the dry sub layers. Travel on the site at Addiewell was good, with excellent traction and no ground disturbance.

The Dalquhandy site was wet, which helped the excavator dig into the 'softer' ground compared to Addiewell. However, the surface of the access routes soon 'churned' up and travelling with the machine on the treated plot became difficult.

The transportation of the compost by the excavator from stockpile to plots would not be used in a large scale operation. However, the outputs and costs of the cultivation by excavator are considered realistic for machinery that may be used.

### Cost/output

Addiewell (hard, dry shale site)

Cultivation and mixing with amendment cost **c £5,000 / ha.**

An estimate based on previous studies of the total cost including placement of amendment is **c £6,100 / ha.**

[3] Jackson, F. & Wall, M. (2009, unpublished). Cultivation & Compost Mixing, Dalquhandy: Work Study

Dalquhandy (soft, wet clay site)
Cultivation and mixing with amendment cost **c £2,500 / ha.**
An estimate based on previous studies of the total cost including placement of amendment is **c £3,600 / ha.**

# Recommendations

## Operational/working practice

The machine worked well given the different conditions. However, in operational circumstances, consideration has to be given to the timing of cultivation and provision of 'drainage taps' to allow water to escape from cultivated cells. Summer or dry-period working is recommended, especially for the wetter soils such as those encountered at Dalguhandy.

On large scale operations machine choice is critically important to ensure the work can be undertaken efficiently and without undue ground damage with the risk of water pollution and machine bogging. The management, transportation and distribution of the compost/AD to the site must be carefully planned.

## Health and Safety

Risk assessments must be carried out for each task. Guidance can be obtained in the following Forest Industry Safety Accord (FISA) Guides:
FISA 703. Debogging & Recovery of Forest Machines
FIAS 704. Excavators in Tree Work
FISA 802. Emergency Planning
FISA 804. Electricity at Work - Forestry.

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Technical Development
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