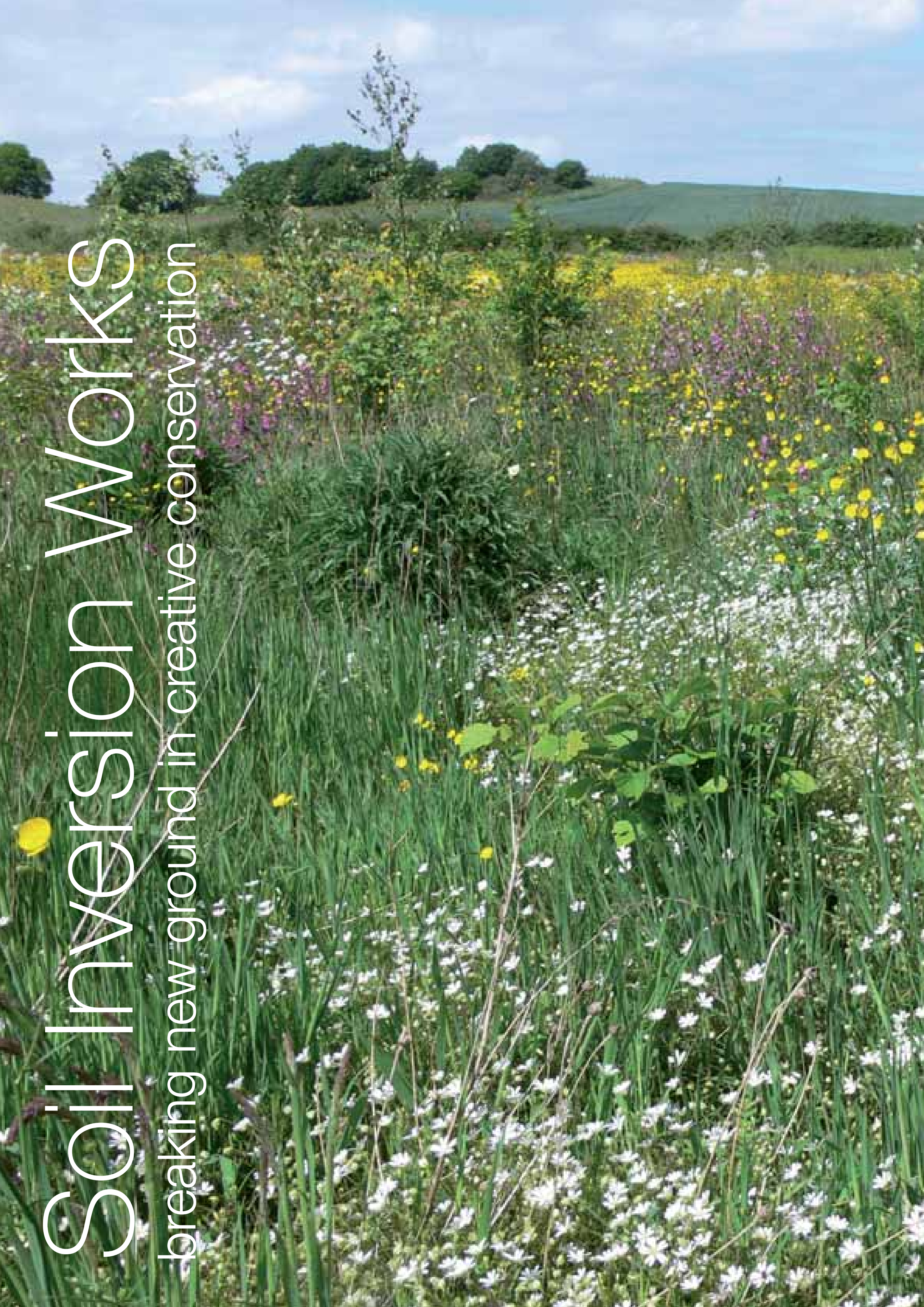

# Soil Inversion Works

breaking new ground in creative conservation

LANDLIFE
creative ▪ protective ▪ ecology

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Landlife is a charity taking action for a better environment by creating new opportunities for wildlife and encouraging people to enjoy them.



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*Front Cover :*
*Soil inversion Wheeldon Copse, Cheshire (Woodland Trust). Broadleaf woodland sown with wildflowers. 2007 (Year 4)*

# Soil Inversion Works

A successful starting point for landscape-scale change to create biodiverse woods, meadows, forests, heaths, dunes and wetlands, which addresses climate change impacts, eutrophication, environmental justice and sustainability.

A five-year Landlife partnership project carried out on 35 sites across the UK.

**Grant Luscombe, Richard Scott and Damian Young**

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## Contents

# Introduction

Creative Conservation is concerned with making new places for wildlife that people can enjoy. Landlife has been seeking simple interventions to create the right starting points for the evolutionary dance to shape new habitats in a rapidly changing environment. In 30 years of creative conservation action on the ground, we are excited by the possibilities of soil inversion to create a wide range of new habitats on a large scale.

Landlife's work in Huyton, Merseyside dating back to the mid 90's involved stripping off topsoil, and sowing on the underlying subsoil with a simple matrix of wildflower species. The result was that in the space of just ten years the total number of species rose from 16 species to 80. Due to the productivity of the grassland being considerably reduced, management was minimised to a very low level and an attractive and popular landscape feature replaced a species poor and neglected one.

Applying these principles to the wider countryside is much more difficult, since obviously whole-scale stripping of topsoil, would be impractical, and remove a valuable resource.

Landlife's work with woodland species dating from the pioneering *Bluebell Recovery Project* (1995) and more recently the national *Woodland Wildflower Project* (2001) has highlighted the need to improve the diversity and attractiveness of woodland ground cover. It has become apparent that most community woodland plantings will have little more interest than trees and grass for many years to come, and have considerable budgets for weed control and management. There is a lack of research on this problem.

For these reasons Landlife developed the idea of soil inversion. This involves turning the weed free and lower fertility subsoil over the nutrient-enriched and weedy topsoil.

The principle of soil inversion is that the inverted soil profile buries the weed seed bank, reduces competition for moisture now held at depth, and makes topsoil accessible only to trees. Deeper rooting of trees improves establishment and growth rates, and produces more robust plantations better able to withstand gales and droughts. Exposed low fertility subsoil provides the ideal growing medium for wildflowers, free of vigorous weed competition. Where combined with tree planting, these sowings may evolve a new woodland flora as humus accumulates under increasing light stress.

In 2000, Landlife hypothesised that trees planted in soil inverted to a depth of a metre would, when compared with traditional forestry:

- be better able to withstand climate change impacts
- have greater establishment success
- have marked biodiversity benefits

Earlier work strongly indicated that low fertility subsoils exposed by this technique would result in the successful establishment of a wide range of new wildflower habitats.

The purpose of Landlife's soil inversion programme (*Break New Ground* 2002-5 and *Forest of Flowers* 2005 -7) was to identify equipment and undertake trials to test this hypothesis.

> *"I gather that this project has proved successful for which you should be congratulated"*
>
> **David Miliband**
> Secretary of State for the Environment
> August 2006

## 2002 -2007 Trials

Trials have been carried out across the UK on 150 hectares (35 sites) between 2002 and 2007. Initially undertaken as an alternative woodland establishment technique, it soon became apparent that it had wider applications. The technique is the subject of a PhD research programme. Although most replicated research plots have a short life these large scale creative conservation trials provide an ongoing evidence base across the decades. Where possible, we have contrasted what we have done against conventional agriculture and woodland planting strategies. As time progresses the scale of this creative conservation project work will become more apparent.

Trials have also been subject to partner appraisal and Forest Technical Development Branch assessment. However, the complexity of soil dynamics, the interaction of nutrients applied historically, and physical changes resulting from soil inversion across these sites make it difficult to draw firm causal relationships. This publication reports on comparative observed effects in the field and draws conclusions where data is supported by independent research.

## Partners

This initiative has been funded by: Defra (2002-5), Esmée Fairbairn Foundation (2003-7), European Commission (2002), Ellerman Foundation (2007-8) and Tanner Trust (2007).

Trials undertaken with Defra support were carried out in partnership with the Eden Project, National Forest, Forest Enterprise, Woodland Trust and English Nature. Further work has been carried out with the Woodland Trust, Butterfly Conservation, Countryside Coincil for Wales, Wildlife Trusts and local authorities.

## Earlier Deep Ploughing

Deep ploughing was carried out in Lincolnshire in the 1950s. Ploughing to a depth of two feet turned up the subsoil. This technique yielded 15-16 tons of potatoes to the acre. Similar agricultural practices were carried out in the 1960s in Holland to bring up sand for carrot growing. In the US the technique was used to reclaim opencast mining sites.

The project undertook a web search and identified work carried out by the Danish Forestry and Landscape Research Institute in 1989 on seven trial sites that achieved soil inversion and an associated project based on four hectares in Lithuania carried out in 1999. These trials did not use wildflower sowings and soil erosion was a matter for concern. In 2002 work on this project was scaled down. However, the Danish findings confirm the benefits for forestry expounded in Landlife's thesis.

# Advantages of Soil Inversion

Soil inversion carried out lighter soils dramatically changes the soil profile resulting in a range of significant benefits for creating new wildflower landscapes, new woodland, and other habitats. The new profile also deals with a range of problems including eutrophication and weed infestation. It creates conditions better adapted to climate change impacts and, when combined with wildflower sowings, offers the possibility of effecting landscape-scale change through a simple intervention.

## Soil

Soil moisture is held at depth, particularly where on the new profile, the grain size at the surface is greater than at depth. This fosters improved nutrient take up of nitrates and phosphates, which have also been placed at depth in the root zone where they are most needed for good tree growth.

Ploughing to a depth of one metre breaks any existing hard pan and aerates the soil. A healthy soil macro-faunal population rapidly develops due to the loosened soil structure. Organic material is placed below the subsoil to create a new soil profile.

The process is reversible. Topsoil can be brought back to the surface by ploughing a second time, thus restoring the soil profile.

## Weeds

Problematic weed seed banks are buried at depth, whilst the dry inhospitable surface layer and low nutrient subsoil discourage weed colonisation. There is therefore no need to sow grass.

## Trees

The new physical and chemical profile of the soil resulting from soil inversion promotes better early root development, faster growing trees with higher survival rates, shorter establishment times and rapid canopy closure. This should result in better quality timber as the higher stem density promotes trees with a better form.

The loose soil structure created by inverting the soil, eases planting, promotes deeper rooting trees and reduces establishment times. This means smaller stock used at lower planting densities, can produce timber outputs that match current forestry practice.

## Biodiversity

The introduction of a limited number of core common wildflower species, as opposed to forestry grasses, produces extensive seed and nectar sources that benefit Biodiversity Action Plan bird, mammal and invertebrate species from year one.

Habitats, which depend on low soil fertility, are in decline throught Britain: bringing subsoil to the surface creates new ones.

Trials using this starting point recruited 64 species in twelve years to create habitat that resembled an MG5 grassland.

The technique can be targeted at a range of habitat types such as, heathland, sand dune, meadow, wetland and woodland. Introducing inoculums of characteristic species, specific to the locality, can safeguard local distinctiveness. These approaches can help build a matrix and link sites of existing nature conservation value. Sowing wildflowers also helps guard against soil erosion.

## Pollution

Traditional forest practice involves the use of grasses to suppress weeds. These grasses rob trees of moisture and therefore require an annual herbicide application over a five-year period. Due to the lack of weed competition arising from soil inversion, uncompetitive wildflower sowings can be used instead of grass. As a result, the annual applications of herbicide are not required, thereby reducing run-off to watercourses and easing maintenance obligations. The successful use of smaller tree stock on soil-inverted sites will also contribute to reduced nursery chemical usage.

By burying nitrates at depth some of the problems associated with nutrient-enriched land are reversed.

## Climate Change

Trees are better adapted to extreme droughts on soil inverted sites due to the better water-holding capacity of the soil and improved root development. Reduced compaction and looser more absorbent soil structure may also reduce run off and potential flood risk.

The global warming potential of nitrous oxide is 296 times more detrimental than carbon dioxide in the upper atmosphere. The Scottish Agricultural College show that deep ploughing reduces this by a factor of five compared with no tillage. The process also contributes to carbon sequestration by burying carbon at depth.

## Sites

Sites within forestry plantations that cannot be targeted for tree planting, such as under electricity pylons or designated open spaces, can be addressed using soil inversion.

Many urban fringe areas consist of outer housing estates adjoining ex-agricultural land. Such sites offer an opportunity to deliver environmental justice (see page 10). Similarly, nutrient-enriched sites coming out of agricultural production and targeted for natural or semi-natural habitat are suitable candidates for this approach.

## Appearance and Community

The use of cornfield annuals to prevent erosion and act as a nurse crop in year one, followed by wildflower perennials, stimulates huge popular acclaim. Sites treated in this way have inspired poetry, letters of praise and YouTube™ postings. People are attracted to these sites in their droves, thus generating interest in forestry practice, habitat creation and biodiversity.

People can be engaged in directly improving their own environs by participating in sowing the sites with wildflower seed.

## Policy

The technique makes a positive contribution to achieving Biodiversity Action Plan and woodland planting targets, and helps deliver UK commitments to the Global Strategy for Plant Conservation.

# Disadvantages of Soil Inversion

The majority of current soil research relates to existing soil profiles. Where research has been undertaken on 'deep ploughing', it is generally concerned with standard ploughing to greater depths rather than soil inversion to a metre. As a result there is very little research to draw on in relation to the soil chemistry and micro faunal changes taking place over time as a result of the inversion process.

## Soil

The greatest changes occur in the soil. Inversion destroys existing long-established soil profiles and the existing soil micro fauna is buried.

Working at depths of a metre destroys existing land drains, thus returning land to earlier unimproved conditions.

The exposure of bare soil with a slower colonisation capability creates potential for wind and water erosion.

## Weed

Although weed seed is buried by soil inversion, noxious weed such as thistle can regenerate from depth and proliferate under certain circumstances.

## Trees

Where land drains have been disturbed by soil inversion, water logging can have an adverse impact on tree growth.

## Biodiversity

The introduction of plant species to an area and the creation of a new starting point for the evolutionary dance may result in new habitats that do not fit the National Vegetation Classification. This may alter historical vegetation provenance patterns.

## Climate Change

Whilst soil inversion buries carbon at depth without mixing the organic microbial layer with locked historic carbon, there is concern that this historic carbon could be released by the introduction of organic matter to deeper layers. Whether this is the case, and whether it is offset by reduced carbon emissions from weathering as a result of burying the topsoil is not known. Release of historic carbon may occur on the surface layer as fresh organic matter is incorporated into the soil by macro faunal activity.

## Unpredictability

Whilst sowing of wildflowers is a key strategy to reduce spaces for weeds, germination is not guaranteed. Autumn and spring sowings have been known to fail as a result of unusual weather conditions experienced in recent years.

## Sites

A major issue about the technique concerns the threat it poses to archaeology. If used indiscriminately, it will destroy any sub-surface archaeology. Regardless of the end habitat, it is critical to ensure that any site targeted for soil inversion is professionally checked for archaeological interest at the outset.

The large-scale equipment used, limits site selection in relation to access, slope and soil depth.

## Cost

Analysis of costs for new woodland establishment compared with standard forestry techniques show that soil inversion is more expensive in the short term. Over the long term costs are greater at higher wildflower sowing rates, but comparable when using lower sowing rates.

*Wheeldon Copse, Cheshire. Soil inversion year 4.*

# Recommendations

## Site Selection

It is essential that sites are of low ecological value and are not of archaeological interest.

The technique should not be employed in archaeologically sensitive areas. A local archaeologist should always be consulted before any works are carried out.

Soil inversion should not be used on sites of faunal or floral interest. A full vegetation survey should be carried out before any works commence and local conservation groups should be consulted.

The technique is best targeted on light well-drained soils in lowland Britain by referring to local geology and soil survey data. These soils are considerably more successful than heavy clays. Always check subsoil quality and depth by digging a series of pits across the site and research former site usage to determine site suitability for ploughing depth and target habitat. For example, the presence of land drains and old drainage ditches will create different long-term conditions compared with a site situated on a sandstone ridge.

For health and safety involving deep excavation work, obtain service information from utility companies.

Select large sites that are accessible. The machinery involved is cumbersome and a route will need to be planned. Entrance widths and drop off points for low loaders will need to be carefully assessed. Try to identify sites that link existing habitats and help to build a large-scale landscape matrix for nature conservation purposes. Opt for sites that have public access and offer a substantial area for long-term meadow establishment.

## Site Preparation

All existing vegetation should be treated with a translocating herbicide 14 days prior to ploughing. Deep plough using a machine suited to the soil conditions as recommended in the technical section. Depending on conditions, plan to work at a rate of 2-3 hectares per day, and monitor soil depth as ploughing progresses. It may be necessary to modify areas of soil inversion as the subsoil is exposed. Excessively heavy areas of clay or bedrock may damage equipment and delay operations.

Operators need to carry sufficient spare parts. Plough points will wear more rapidly on sandy subsoils and will require replacement during operations. Ensure the plough is fully lifted before turning and work at reasonable speeds. Inexperienced operators may not be familiar with the size of the plough or may work at high speeds unaware of the excessive stresses and strains involved. Risk assessment and Health and Safety appraisal must be undertaken prior to commencing operations.

Work parallel to the contour to minimise soil erosion. Harrow the site immediately after ploughing and apply a second herbicide application twenty-eight days later if necessary. As soon as the herbicide has taken effect or if no weeds appear, sow with wildflower seed using standard calibrated agricultural combination seed drills. Use the opportunity to engage local people in broadcasting some of the wildflower seed by hand. The site is then ready for any tree planting operations.

If working on clays, harrow several times in dry conditions to obtain a good tilth. Frost action will break clods. Expect slower colonisation; bare areas will remain but are a good habitat for invertebrates. Hold back some seed for sowing bare areas later.

## Species Selection

Select a small number of common core native British wildflower species. To prevent soil erosion and reduce weed competition, include short-lived annuals and biennials in wildflower seed mixes. Include a range of perennial species to evolve over time. Vary mixes to suit subsoil conditions across the site and to meet long-term target habitat objectives. Sow annuals at 2-5g/m² and biennials/perennials at 0.5-1g/m².

Source locally characteristic species to maintain local distinctiveness, and incorporate features to increase biodiversity potential - old logs, boulders, vertical surfaces and ditches. Work with nature by allowing the evolutionary dance to shape the habitat structure.

Use small tree stock, as establishment and early growth is rapid. Plant trees in natural drifts parallel to prevailing winds. Select tree species to suit the locality.

On sloping sites, plan to leave grass erosion control strips on the contour. These may be incorporated as part of a path network for public access.

## Management Operations

It may be necessary to hand weed or spot herbicide isolated weed invasion before the herbaceous layer is fully established. Follow-up sowings may be necessary if initial germination in year one is poor. Open grassland will benefit from several passes with a tractor-mounted flail in September.

These sites have proved to be hugely popular with local communities. Plan to manage this with information on site about the technique and invitations to comment and contribute to visual records.

The rapid increase in wildlife on site needs to be monitored. Engage qualified surveyors to undertake periodic bird, invertebrate and vegetation surveys. This will be valuable information for future projects, as the site will have started as bare ground with no biodiversity.

### Timetable of Establishment Operations.

| Month | Year 1 | Year 2 |
|---|---|---|
| May | Flail site | Hand pull any Ragwort *(Senecio jacobaea)* |
| June | Spray using a Glyphosate based herbicide | Survey site |
| July | Deep plough and harrow | Spot herbicide noxious weeds if necessary |
| August | Re-apply Glyphosate based herbicide | Flail |
| September | Sow annual and perennial wildflower seed | Over-sow any bare areas |
| October/November | Plant trees if required | Replace any tree losses |

# Environment of Change

In the light of climate change impacts, it is not possible to maintain the status quo and a more flexible adaptive approach to the conservation of ecosystems is needed. This may include the expanding and linking areas of wildlife value to protect less mobile species. Soil inversion offers an elegant approach to offering large-scale change on nutrient-enriched land in lowland Britain by creating the right conditions for new habitats to evolve.

## Policy Context

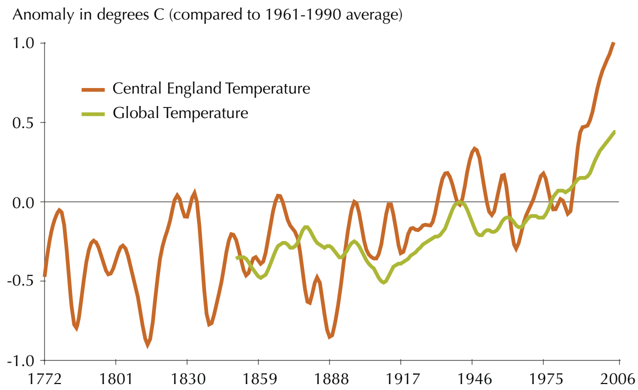
The soil inversion programme responds to a policy framework aimed at returning land to semi natural habitat, and improving the natural environment for people's enjoyment. It demonstrates Landlife's significance as a catalyst of direct relevance to Defra's *Working with the Grain of Nature, Standards of Sustainable Forest Management* and *England's Trees, Woods and Forests*. The project seeks to deliver public benefits and longer-term solutions to these contemporary landscape problems by connecting woodland project work to wider Government strategies and demonstrating capacity building within our partner groups. New woodlands established this way could be good for wood fuel production, landscape-scale conservation, stepping-stones for wildlife moving north and buffering habitats.

The project has helped the UK to meet Biodiversity Action Plan commitments under the Global Strategy for Plant Conservation adopted in 2002. The soil inversion technique was highlighted in the UK's response to the strategy (*Plant Diversity Challenge:* Plantlife/JNCC 2004) as a way of demonstrating *'that wild flowers can return to agriculturally improved land by restoring the right conditions and lowering fertility.....'*

## Climate Change

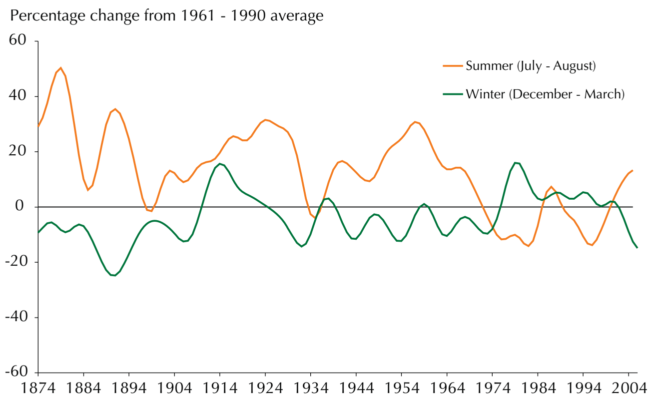
By 2080 it is forecast that there may be a 50% decrease in summer rainfall with a corresponding 20% increase in winter rainfall. Clearly, new approaches to tree planting and moisture retention are needed to cope with these scenarios and the unpredictable incidence of extreme climatic events.

### Average surface temperature: 1772-2006 Global and Central England.




*Source: Hadley Centre. Crown Copyright "The Environment in Your Pocket" 2007.*

### Seasonal precipitation, high summer and winter: 1874-2005.



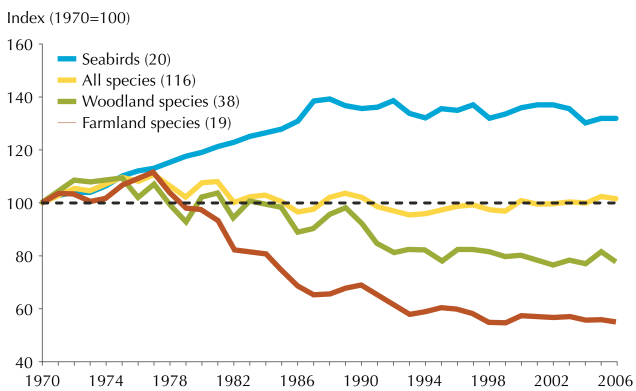

*Source: Hadley Centre. Crown Copyright "The Environment in Your Pocket" 2005.*

## Loss of Biodiversity

The *New Atlas of British and Irish Flora* (2004) highlights the decline of species associated with low fertility habitats and the increase in those of high fertility, over a 40-year period. Over a similar period, the Bunce Report identified that the average number of plant species in native wood plots declined by over 30%. In the West Midlands, Defra recorded farmland bird populations declining by 14% and woodland bird numbers falling by 6% between 1994 and 2004. By 2005, only 12% of the UK had woodland cover and 7 million hectares of lowland agricultural Britain was of little or no ecological value. Under Government policy to increase woodland cover, new woods are being targeted on this land. However nutrient pollution has been identified as a major problem in the countryside. High levels of residual soil fertility hinder the establishment of species-rich habitats and trees due to intense weed competition for light and moisture.

Soil inversion is specifically targeted at creating habitats to help reverse these shocking trends.

**Population of wild birds: 1970-2006**
**United Kingdom.**




*Source: Defra, RSPB, BTO. Crown Copyright "The Environment in Your Pocket" 2007.*

## Local Distinctiveness

It is estimated that habitats may be moving northwards and uphill at a rate of 50-80km per decade *(Department of the Environment, Transport and Regions, 1998).* The Rothamsted Park Grass Experiment demonstrates that marked evolutionary changes occur in less than a decade through adaptive variation, resulting in species developing local characteristics that reflect the dynamic nature of natural processes.

## Environmental Justice

People who have the most urgent environmental needs are those who live with the consequences of a poor quality of life, and live in depressing environments - close to polluted brooks, bland parks filled with litter and green deserts. Better-off communities would not accept this, and those who have to endure such environments in which to bring up a family, or grow old themselves, are being denied environmental justice.

Environmental justice can be delivered through procedural and distributional reform. Bringing biodiversity to these communities helps address some of the distributional inequalities, builds inter-generational equity and engages people in new procedural practices and processes.

# Technique & Equipment

## The Inversion Process

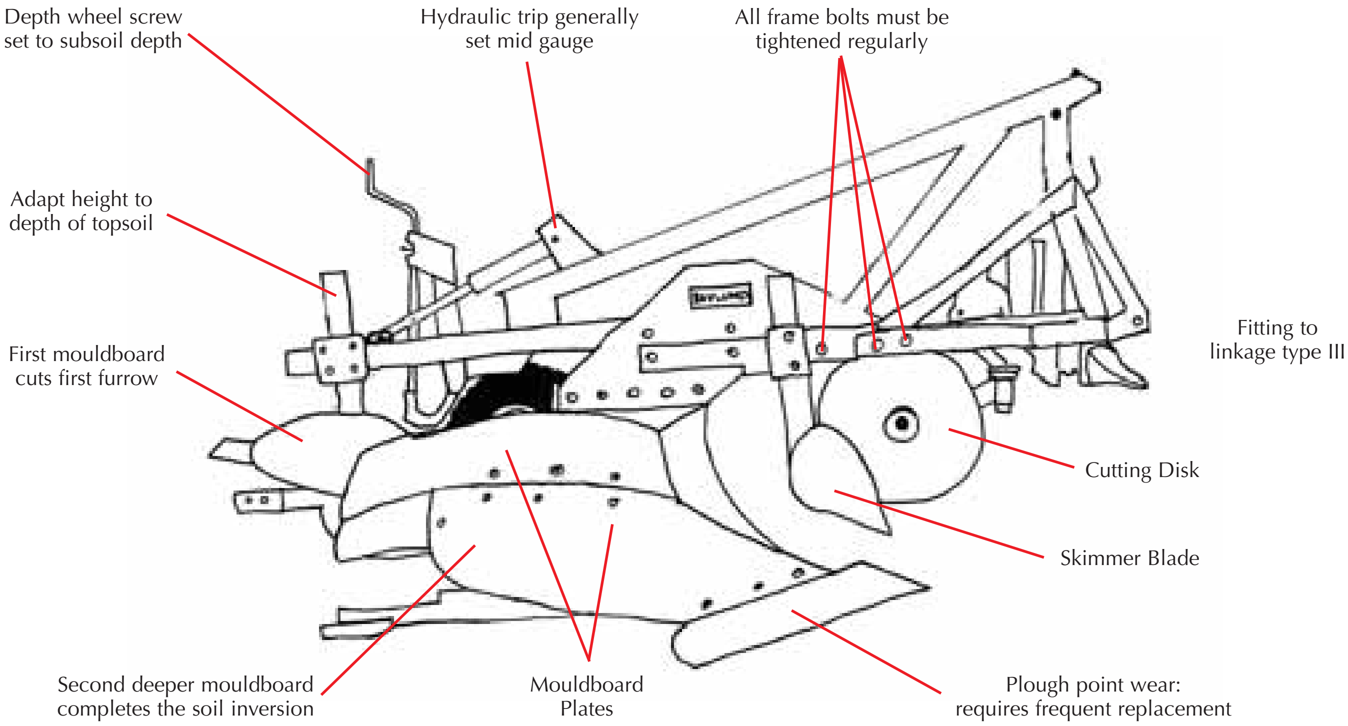
A smaller ploughshare following the main ploughshare tills a new furrow by cutting the topsoil layer and turning it into the previously excavated deep furrow.

The main ploughshare works in the bottom of the furrow created when the topsoil was turned into the deep furrow. It lifts and turns the subsoil layers onto the inverted topsoil, in the process creating a new deep furrow into which the topsoil will be turned on the next run.

Repeating the process over the ploughed land, thereby returning the topsoil to the surface can restore the original soil profile.


**Landlife: Soil Inversion Profile 2004.**


**Danish Forestry and Landscape Research Institute: Soil Inversion Profile1993.**



## Obtaining the Best Results

Best results are achieved on light sand, silty or gravely soils where the speed of the plough can be maintained, resulting in a better 'soil flip'.

Where heavy subsoils have been inverted, adherence to the ploughshare causes partial inversion, resulting in the risk of weed and grass exposure at the surface.

The inversion results are dependant on:

- Machinery torque
- Machinery speed
- Traction

*Cutting the first furrows.*

- Soil type.
- Soil moisture
- Plough depth

*Long grass and heavy soils inhibit the 'soil flip'.*

- Surface vegetation
- Operator experience
- Field configuration

*Light subsoil (left) buries the dark topsoil (right).*

## Other applications

The technique can also be applied to the creation of modern ridge and furrow by ploughing in opposite directions. This is a slow process, as it requires a new furrow to be opened on each occasion.

Ditch systems can also be created by leaving final furrows open or double ploughing the final furrow.

*A ditch created using the technique.*

## Plough

The project utilises a Bovlund 64D plough sourced from Denmark. The plough uses a double ploughshare with mouldboards to invert the soil profile between 500mm and 1000mm. Conventional ploughs work to a depth of 250mm.

Turning a metre of soil requires the use of the largest tractors in the country. Ploughing on heavy soil puts both plough and tractor under enormous strain. In some cases, turning 1m of heavy clay soil is beyond the capability of even these machines.

## Machinery Assessment

The project has tested a variety of tractors, on different soils.

*John Deere 150HP.*

Insufficient traction achieved on capped china clay waste resulting in wheel spin and an incomplete inversion. Not suitable.

*John Deere 4995 -180 HP.*

Heavy and powerful wide-wheeled machine, capable of a good inversion on lighter subsoils. Less effective on very heavy soils. More effective with double tyres fitted.


*CAT Challenger 56 240 HP.*

The tracks of this vehicle create a neatly pressed topsoil furrow resulting in a clear stratification as it is overlain by subsoil on the second run. The increased ploughing speed achieved by this machine improves the inversion 'soil flip' on both light and heavy soils.

*CASE STX 325 350 HP.*

This very large wheeled tractor is capable of a fast complete inversion, even on heavier subsoils.

*CASE STX 500 500HP.*

The four tracks on this very large machine aid manoeuvrability, however its size affects the mode of operation resulting in a weaker 'soil flip' but its sheer power enables it to maintain a steady passage on more challenging sites.

## Output

With the most efficient machinery on light soils it is possible to invert an area of 2 to 3 hectares a day. Heavier soils and slow machinery reduce this rate.

## Operational Maintenance

The amount of wear and tear on the plough is dependant on the nature of the subsoil. Coarse sandy soils erode plough parts faster than heavier clay soils. On average points require replacement approximately every 6 hectares. The sturdy plough construction incorporates sheer bolts enabling it to cope with boulders. However, damage has been sustained on bedrock and old foundations not identified before ploughing.

*Wear on the points is greater on sandy subsoils.*

Operational stresses and strains loosen bolts. Regular inspection and tightening during the course of ploughing is essential to maintain the integrity of the frame.

## Sowing Operations

Preparation for seed sowing following soil inversion is undertaken using standard agricultural harrows and combination seed drills. If using other seed drills ensure that there is a loose tilth and set drill as shallow as possible. Drills need to be re-calibrated to ensure seed is distributed evenly at the required sowing rate. By using a carrier such as bran or barley meal, small quantities of wildflower seed can be bulked up at a rate of 5 parts bran to 1 part seed, so that these machines can be used for this purpose.

*Harrowing inverted soil ready for sowing.*

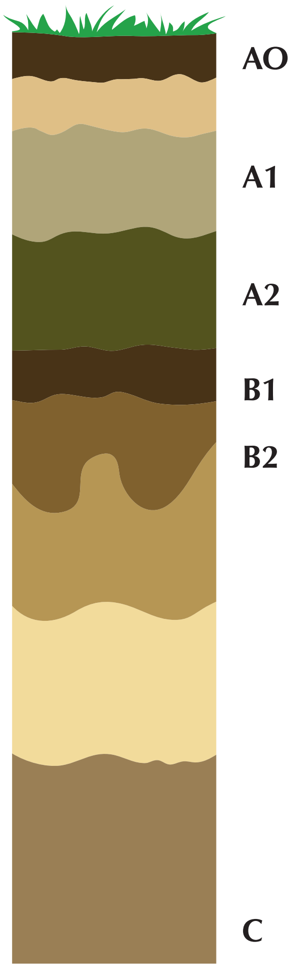
*Bran used to bulk up seed.*

*Calibrating the combination seed drill.*

# Soils

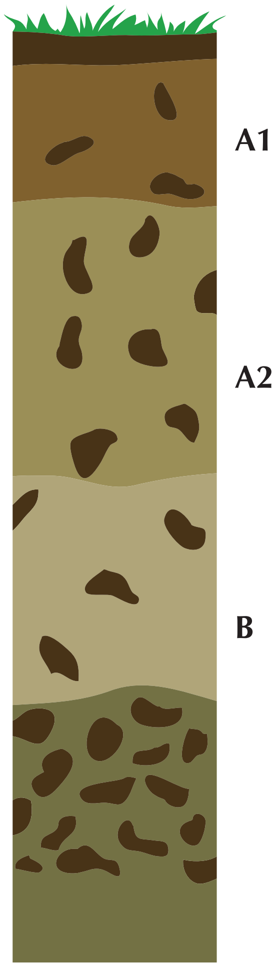
This project has been carried out on 35 sites across the UK. These have included highly eutrophic agricultural arable land, neglected grassland, abandoned airfield, damaged dune system and capped mine waste. Wide ranges of soil types and grain sizes have been ploughed, including sands, silts, gravels and clays. Findings have been focused on typical light subsoils and heavier clay subsoils.

On arable sites a hard pan and land drains were regularly encountered using the Bovlund plough.



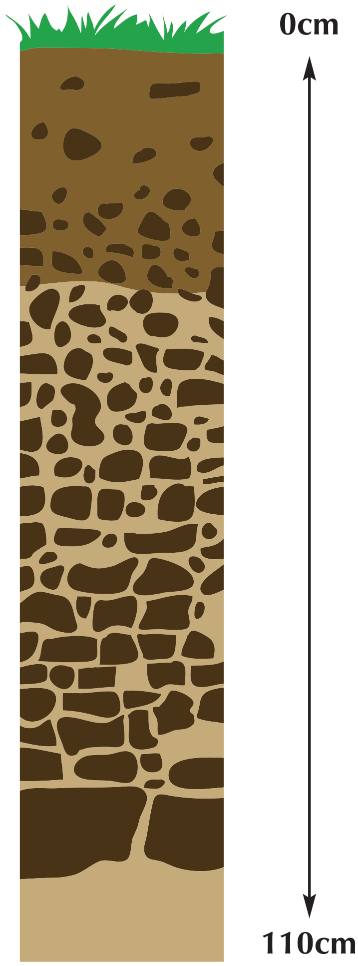

### PODSOL

The hard pan (B1) will be broken by deep ploughing. A plough depth of between 70 and 100cm will expose the lights sandy subsoil (B2 and below). The rich humus layer (A0 and A1) will be buried. These are ideal soil conditions for inversion.




### BROWN EARTH

Consists of varying degrees of heavy clay. Soil inversion will bury the humus layer and bring up heavy clay from between 60 and 80cm (B).




### RENDZINA

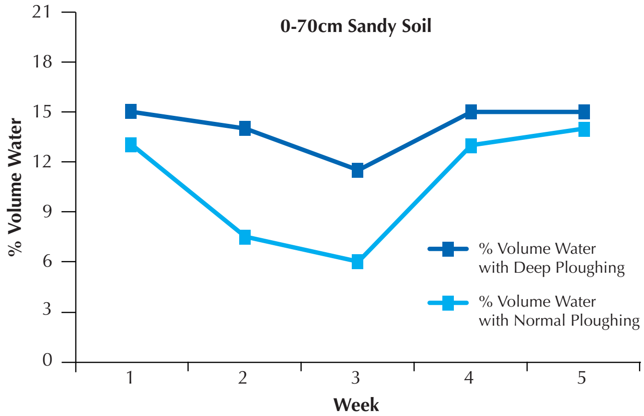
The very shallow soil layer (20cm) overlies chalk bedrock. Soil inversion is not necessary and other methods of establishment should be used on the low nutrient topsoils present.

*Soil profile of inverted site clearly showing the buried thatch layer still visible after 4 years.*

*A 1cm layer of topsoil built up 4 years since inversion.*

## Soil moisture

Working on light soils, a total inversion to one metre has been achieved. Danish and Manchester Metropolitan University trials confirmed that moisture is held at depth on these types of soil. Moisture is most effectively held were the surface profile graduates from larger to smaller grain size. This effect is not seen on heavy soils.




*Soil Moisture held at depth.*
*Danish Forestry and Landscape Research Institute 1995.*

## Subsoils

Subsoils are highly variable across a site and not all subsoils are of a low fertility composition. Clay subsoils tend to be more fertile, but analysis of Nitrogen and Phosphorous levels is needed to confirm fertility levels at specific sites.

*Subsoil samples. Lunt, Merseyside.*

## Subsoil variation on the inverted sites across Britain.

*Prees Heath, Shropshire.*

*Runcorn, Cheshire.*

*Hedley Hall, Tyne and Wear.*

*Coton Wood, Leicestershire.*

*Burroughs Wood, Derbyshire.*

*Hedley Hall, Tyne and Wear.*

## Soil Fauna

The poor soil fauna associated with arable soils is buried by soil inversion. Observations confirm that the new soil profile is rapidly re-colonised. A study showed more extensive and varied populations of Springtails *(Collembola)*, Beetle larvae *(Coleoptera)*, Fly larvae *(Diptera)*, Myrapods, Mites *(Acrina)*, Spiders *(Aranae)*, Woodlice *(Isopods)*, Slugs and Snails *(Gastropods)*, *Oligichaetes* and *Nematodes* were present at an inverted site 4 years after ploughing compared with adjacent contemporaneous traditional forest plantations.

## Erosion

Sites may be susceptible to soil erosion if left bare. A level sandy site with a high water table sown with slow growing perennials suffered a degree of water and wind erosion over the first year, resulting in the emergence of weeds from the now partially exposed topsoil. This effect has been overcome on steeper slopes by contour ploughing, sowing grass strips and introducing annual wildflower species to bind the soil.

*Water erosion, Merseyside.*

*Wind erosion, Merseyside.*

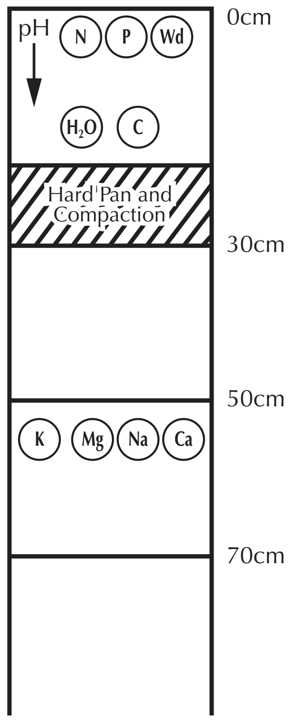
*Grass strips to prevent erosion, Leicestershire.*

## Soil Chemistry

A PhD project carried out by Manchester Metropolitan University assessed the effect that the inversion process has on the chemical properties of soils. The technique was compared to conventional ploughing. The table below is a summary of the findings.

| **Soil factor** | **Main effects of deep ploughing** |
|---|---|
| Water | No immediate effect of deep ploughing on soil water content. Some evidence that soil water content increases in deep ploughed soil at depth after rainfall soaks down. |
| pH | Deep ploughing raises pH of surface soil more than conventional ploughing, where original subsoil has higher pH. Effect may vary depending on original soil pH profile. Effect appears to persist long-term (3-5 years). |
| Organic matter | Deep ploughing lowers surface soil organic matter and increases buried soil organic matter. Effect is highly significant and persists long-term (3-5 years). |
| Nitrogen (N) | Deep ploughing lowers surface total N and increases buried soil total N. Effect is highly significant and persists long-term (3-5 years). Effect on soil nitrate and ammonium levels less evident due to their high mobility in the soil profile, and may also be affected by original soil type. |
| Phosphorous (P) | Deep ploughing lowers surface total P and increases buried soil total P. Effect is highly significant and persists long-term (3-5 years). Similar results for soil phosphates (the form of P that is available for use by plants). |
| Potassium (K) | Deep ploughing increases surface total K and decreases levels at depth. |

*Main effects of deep ploughing compared to conventional ploughing. Acknowledgement: Glen et al (2008), Manchester Metropolitan University.*

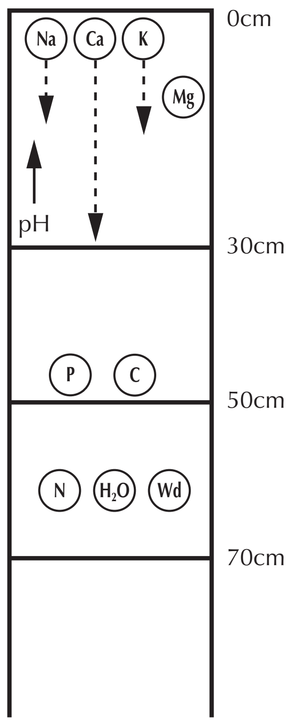



## Conventional Plough

pH rising with depth
Shallow rooting into moist fertile soil
Drought affects first foot of soil - problem for establishing trees
Drought will encourage deeper rooting in established trees
High carbon in organic matter released by microbial activity and weathering

Hard Pan and compaction

Little loss of moisture by evaporation
Loss of water by slow drainage downwards
Historic carbon locked in subsoil
Salts leached into subsoil



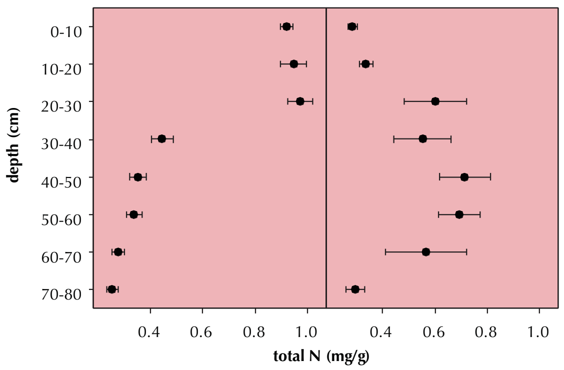

## Soil Inversion

pH falling with depth
Dry sandy surface reduces weed colonisation
Rapid extensive root colonisation to 60cm resulting in improved tree establishment and drought resistance
Raised pH and calcium levels help plants to take up mineral nutrients more readily
Salts rapidly move down the soil profile in sandy soils
Reduced nitrous oxide emissions
Low phosphate levels good for wildflowers
Sand grain size reducing with depth best for reducing water evaporation
Soil aerated

Greater development of roots in the 30-60cm zone
Deep N& P (fertilizer) placement in root zone
Greater moisture at depth
Best growth where roots in moist fertilizer zone

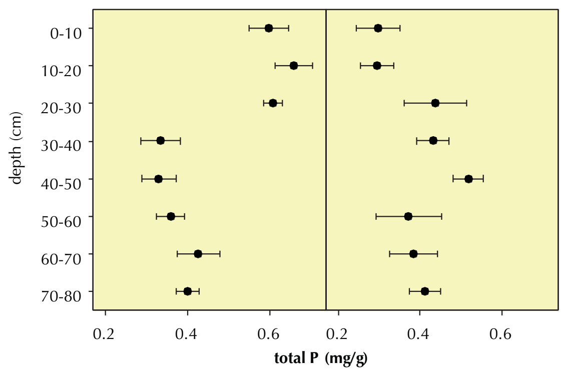
Surface carbon buried at depth
Reduced denitrification
Distinct zones - no mixing of organic material and historic carbon
Weed bank buried

## Nitrogen



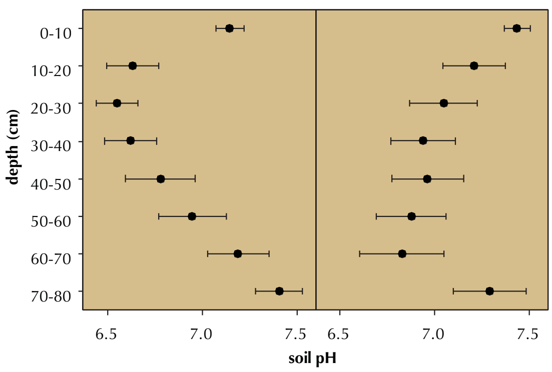

*Soil total nitrogen (N) in each 10 cm depth section of the soil profile in conventionally ploughed (left) and deep ploughed (right) soil four days after ploughing. Mean +/- SE. N = 8. Significant differences: conventionally ploughed > deep ploughed at 0-10 cm, 10-20 cm and 20-30 cm; deep ploughed > conventionally ploughed at 40-50 cm and 50-60 cm. Acknowledgement: Glen et al (2008), Manchester Metropolitan University.*

## Phosphorous



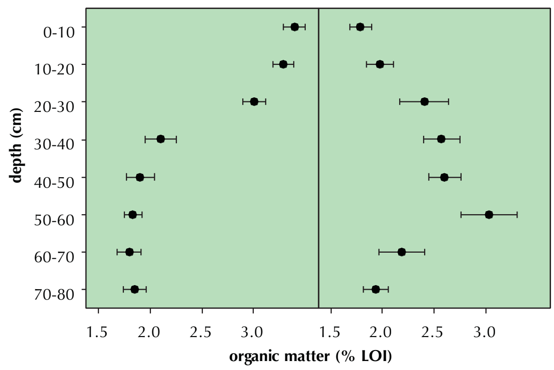

*Soil total phosphorous (P) in each 10 cm depth section of the soil profile in conventionally ploughed (left) and deep ploughed (right) soil four days after ploughing. Mean +/- SE. N = 8. Significant differences: conventionally ploughed > deep ploughed at 0-10 cm and 10-20 cm; deep ploughed > conventionally ploughed at 40-50 cm. Acknowledgement: Glen et al (2008), Manchester Metropolitan University.*

## Soil pH




*Soil pH in each 10 cm depth section of the soil profile in conventionally ploughed (left) and deep ploughed (right) soil four days after ploughing. Mean +/- SE. N = 8. Significant differences: deep ploughed > conventionally ploughed at 0-10 cm, 10-20 cm and 20-30 cm. Acknowledgement: Glen et al (2008), Manchester Metropolitan University.*

## Organic Matter




*Soil organic matter in each 10 cm depth section of the soil profile in conventionally ploughed (left) and deep ploughed (right) soil four days after ploughing. Mean +/- SE. N = 8. Significant differences: conventionally ploughed > deep ploughed at 0-10 cm, 10-20 cm and 20-30 cm; deep ploughed > conventionally ploughed at 40-50 cm and 50-60 cm. Acknowledgement: Glen et al (2008), Manchester Metropolitan University.*

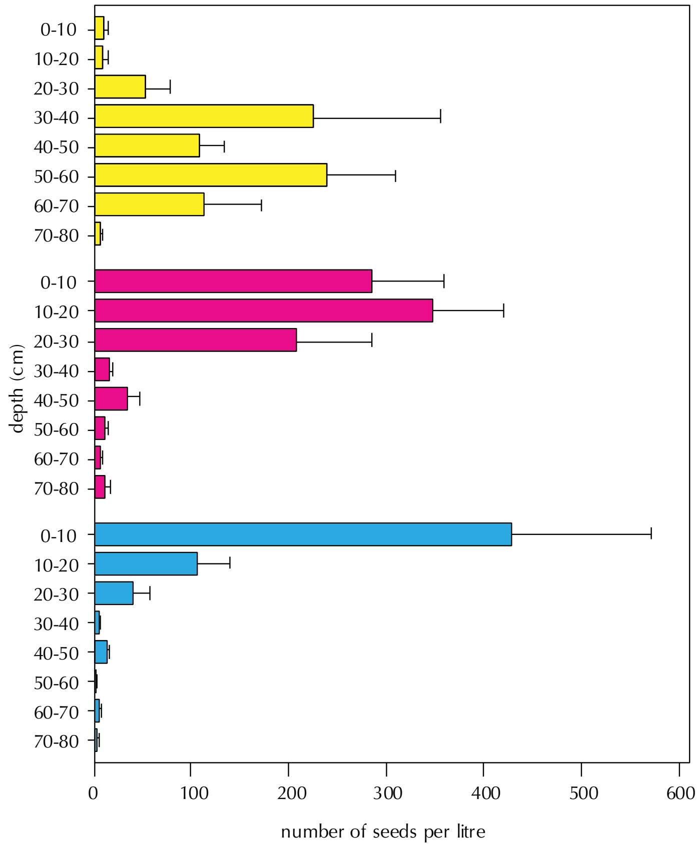
# Weeds

Conventional forestry techniques involve shallow cultivation, and tree planting combined with competitive grass sowings at high densities. This results in a thick grass mat, which whilst directly competing with the newly planted trees for water and nutrients, discourages infestation by noxious weeds such as Docks *(Rumex sp.)* and Thistles *(Cirsium sp.)*.

The soil inversion technique eliminates the need for sowing grass as it buries the weed seed bank up to 1 metre below the surface.

## Weed Risk on Inverted Sites

Sites prone to weed infestation include: sites not pre-treated with herbicide, narrow strips surrounded by weed infested land, areas of poor wildflower germination, and central topsoil ridges left by ploughing in opposite directions.




*Graph to show the v ertical distribution of seeds germinated from deep ploughed (yellow), conventionally ploughed (pink) and unploughed (blue) soil. Bars show mean number of seeds per litre + SE for all species. N = 8.*
*Acknowledgement: Glen et al (2008), Manchester Metropolitan University.*

*Creeping Thistle (Cirsium arvense) regeneration due to no early herbicide treatment.*

*Ragwort (Senecio jacobaea) invasion into a narrow strip.*

*Dock (Rumex obtusifolius) on the topsoil ridge.*

Excavations following soil inversion show that deep-rooted species such as Creeping Thistle *(Cirsium arvense)* regenerate from root cuttings a metre below the surface. The problems associated with re-infestations can be eliminated by the application of translocating herbicides. The initial pre-ploughing application needs to be followed by a second application after deep ploughing. This ensures that surviving deep roots are brought to the surface for herbicide treatment. These treatments should be carried out 14 days prior to ploughing and 28 days after the ground has been cultivated.

Forest Research trials carried out at Fordham in Essex compared soil inversion with various mulches and thermal treatments to assess their effectiveness at suppressing weed growth in newly planted tree plots. Their report *Non Pesticide Tree Establishment Trials 2003* published in 2006, concluded that topsoil inversion was the most effective non-herbicide method.

However, these trials were prone to weed invasion as they had:

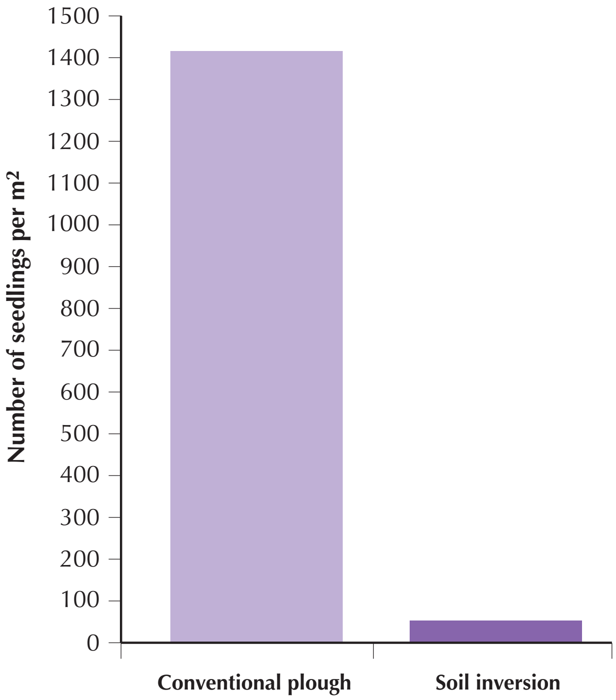
- No pre-plough herbicide treatment
- An ineffective soil flip due to heavy soils
- Small-scale plots
- No nurse crop sowing

Exposed bare ground may be susceptible to colonisation by wind blown noxious weed species. However, light subsoils with large to small soil grain size profiles provide inhospitable conditions for weed germination, but allow fast-growing annuals to establish. Thus non-invasive annual wildflowers can be sown as a nurse crop for perennial species. The annuals shelter the slower-growing perennials and reduce gaps for weed colonisation.

*Cornfield annuals in Grantham, Lincolnshire.*

| Species | Soil inversion (mean number of seedlings per m²) | Conventional plough (mean number of seedlings per m²) |
|---|---|---|
| Knotgrass *(Polygonum aviculare)* | 40.3 | 1128.0 |
| Wild Oat *(Avena fatua)* | 2.6 | 0 |
| Scentless Mayweed *(Tripleurospermum inodorum)* | 2.6 | 72.0 |
| Redshank *(Persicaria maculosa)* | 1.0 | 0 |
| Common Mouse-ear *(Cerastium fontanum)* | 0.3 | 72.0 |
| Fat Hen *(Chenopodium album)* | 0.3 | 36.0 |
| Annual Meadow Grass *(Poa annua)* | 2.3 | 0 |
| Charlock *(Sinapis arvensis)* | 0.6 | 0 |
| Field Pansy *(Viola arvensis)* | 1.0 | 0 |
| Field Bindweed *(Convolvulus arvensis)* | 1.3 | 36.0 |
| Sheep's Sorrel *(Rumex acetosella)* | 0.3 | 0 |
| Creeping Thistle *(Cirsium arvense)* | 0.3 | 36.0 |
| Corn Spurrey *(Spergula arvensis)* | 0 | 36.0 |
| **Total** | **52.9** | **1416.0** |

**Graph to show the mean number of weed seedlings per m² conventional plough and soil inversion (ground left unsown), at Lunt, Merseyside.**




*Creeping Thistle (Cirsium arvense) infestation at traditionally planted (herbicide treated) site.*

# Trees

Tree growth is faster on deep ploughed light soils compared with those planted using conventional methods. The difference can be as much as a factor of three for some species when combined with wildflower sowings. Tree root penetration is also faster and root balls are significantly more extensive. In first year whips, roots have been recorded in the buried nutrient rich topsoil 70cm below the surface. The benefits of soil inversion on tree growth are reduced on heavier soils although some increased growth does occur.

Trees planted on areas that have been deep ploughed and sown with grass show no increased growth when compared to traditional techniques. This is due to moisture competition from the thick grass thatch, a problem with which traditional forestry is familiar.

*Lunt, July 2003: Soil inversion & wildflowers.*

*Wheeldon Copse, June 2007: Soil inversion & wildflowers.*

*Lunt, July 2003: Traditional forestry and grass.*

*Wheeldon Copse, June 2007: Traditional forestry and grass.*

*Lunt, Larch (Larix decidua) year 2.*
*Left tree: traditional forestry with rip.*
*Right tree: soil inversion with wildflowers.*

*Lunt, Silver Birch (Betula pendula) year 2.*
*Left tree: traditional forestry with rip.*
*Right tree: soil inversion with wildflowers.*

## Tree seeding

Work by the Swedish University of Agricultural Sciences (2004) found that the highest Silver Birch *(Betula pendula)* seedling survival rate occurred on silty and sandy sites prepared by either removing the topsoil or deep ploughing. The tallest seedlings were found where the topsoil was retained in the soil profile by deep ploughing.

In late 2007 the Woodland Trust experimented with direct tree seeding two soil inversion sites.

*Scouts sowing Oak (Quercus robur) seed in Cheshire.*

## Tree Mortality

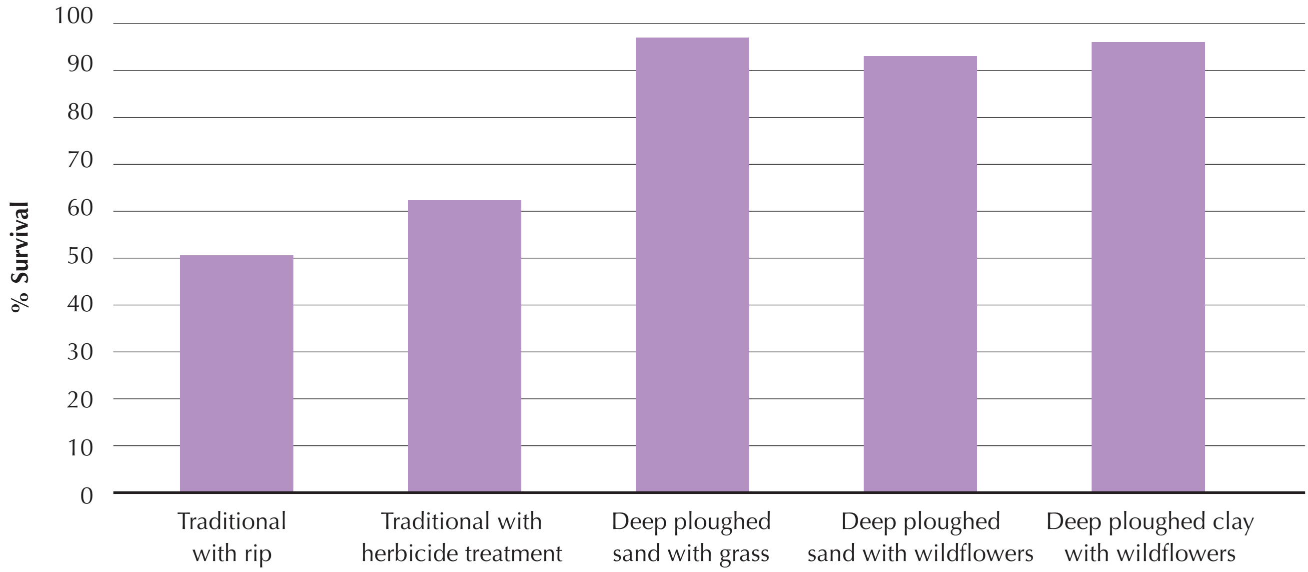
In traditional forestry a mortality rate of 30% is standard. Deep ploughing reduces mortality to negligible proportions, with 99% survival rates recorded on inverted light soils sown with wildflowers. Forest Research recorded that *'No planted tree mortality was evident'* at the deep plough trial sites in Fordham, Essex.

Reduced tree mortality on soil inversion sites in the severe summer drought of 2006 was due to trees accessing moisture retained in the buried topsoil.

*Soil inversion Wheeldon Copse, Cheshire, August 2006.*

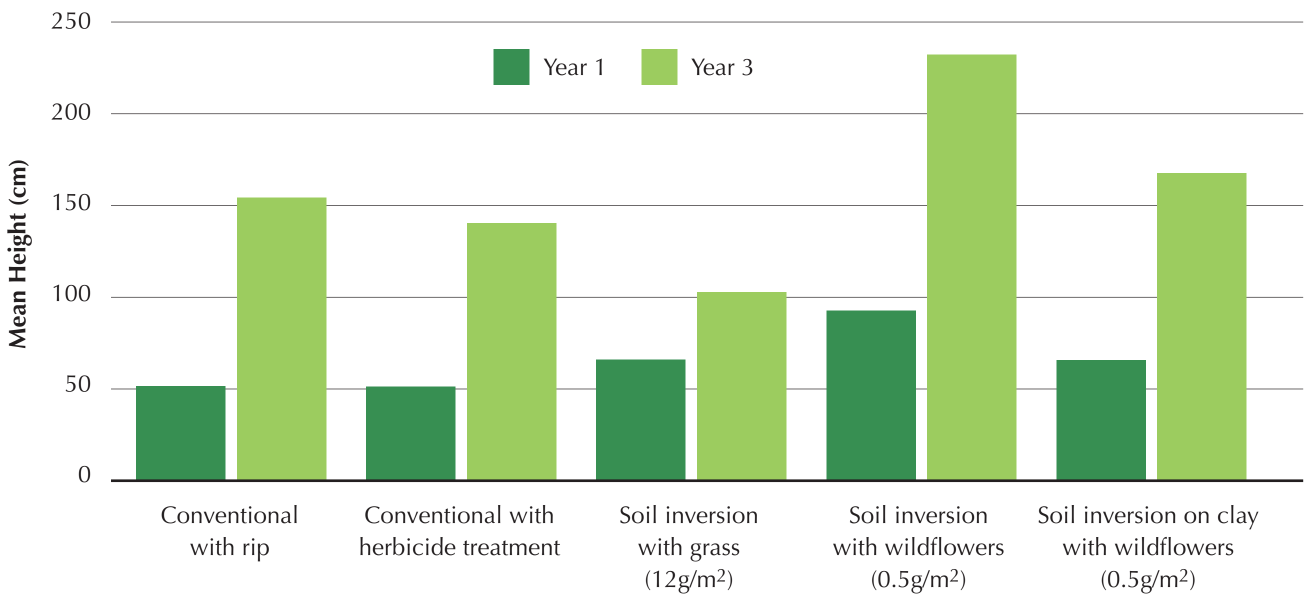
*Adjacent traditional Forestry, August 2006 (same day).*

**Graph to show percentage tree survival, for all species, at Lunt 3 years after works.**




A survey at Lunt, Merseyside concluded that the lowest mortality rates were in the trees planted on deep ploughed areas sown with grass (2%) and the deep ploughed clay sown with wildflowers (3%). The greatest tree mortality was found on traditionally prepared land that was ripped (49%) and traditionally planted areas that receive an annual herbicide treatment (37%). The area deep ploughed and sown with wildflowers had a survival rate of 94%.

**Graph to show mean tree height (cm), for all species at Lunt, after 1 and 3 growing seasons.**




The greatest mean tree height was found on the deep ploughed area sown with wildflowers (230cm). The least was on ground deep ploughed and sown with grass (102cm).

# Flora

Topsoil inversion creates a low nutrient, weed free starting point suitable for colonisation by wildflowers. The project has advocated the introduction of simple mixes of common wildflowers, which have a wide distribution and are of British provenance.

The topsoil inversion technique offers an opportunity to establish and expand populations of declining wildflower species associated with low fertility habitats. Mixes should be tailored to suit the subsoils exposed by soil inversion.

## Seed Mixes

Landlife advocates the use of perennial wildflowers in conjunction with annual wildflower sowings without the use of grass. Seeds should be sown at a rate of 0.5-1g/$m^2$ for perennial wildflowers and 2-5g/$m^2$ for annuals. Higher sowing rates will be more effective at eliminating competition from the highly aggressive forbs as wildflowers establish more readily. Local grass species gradually colonise but not to the detriment of the wildflowers. Areas sown with 20% wildflower and 80% grass mixes rapidly become dominated by grass to the detriment of wildflower and tree performance.

## Meadow Creation

By using site-specific wildflower mixes, it has been possible to produce floristically-rich communities, which evolve over time. A Merseyside site stripped of topsoil by Landlife 13 years ago gained 64 species through natural colonisation and now resembles a MG5 Grassland. This site is being used as an example for landscape-scale ecological restoration in Germany.

*A 13-year-old subsoil meadow, Huyton.*

## Typical Seed Mixes

| Soil Type | Landlife Wildflowers Mix | Species Composition |
|---|---|---|
| Sandy Loam | Heritage Meadow<br> | Betony *(Stachys officinalis)*<br>Cowslip *(Primula veris)*<br>Field Scabious *(Knautia arvensis)*<br>Kidney Vetch *(Anthyllis vulneraria)*<br>Lady's Bedstraw *(Galium verum)*<br>Musk Mallow *(Malva moschata)*<br>Ox-eye Daisy *(Leucanthemum vulgare)*<br>Ribwort Plantain *(Plantago lanceolata)*<br>Wild Carrot *(Daucus carota)*<br>Yellow Rattle *(Rhinanthus minor)* |
| Medium Loam and Heavy Clay | Traditional Meadow<br> | Lesser Knapweed *(Centaurea nigra)*<br>Meadow Buttercup *(Ranunculus acris)*<br>Meadowsweet *(Filipendula ulmaria)*<br>Red Campion *(Silene dioica)*<br>Ribwort Plantain *(Plantago lanceolata)*<br>Selfheal *(Prunella vulgaris)*<br>St. John's Wort *(Hypericum perforatum)*<br>Teasel *(Dipsacus fullonum)*<br>White Campion *(Silene alba)*<br>Yarrow *(Achillea millefolium)* |
| Light Sands and Calcareous soils | Downland Meadow<br> | Birdsfoot Trefoil *(Lotus corniculatus)*<br>Chicory *(Cichorium intybus)*<br>Cowslip *(Primula veris)*<br>Dyers Rocket *(Reseda luteola)*<br>Greater Knapweed *(Centaurea scabiosa)*<br>Lady's Bedstraw *(Galium verum)*<br>Kidney Vetch *(Anthyllis vulneraria)*<br>Ox-eye Daisy *(Leucanthemum vulgare)*<br>Salad Burnet *(Sanguisorba minor)*<br>Selfheal *(Prunella vulgaris)*<br>Viper's Bugloss *(Echium vulgare)*<br>Wild Carrot *(Daucus carota)* |

| Soil Type | Landlife Wildflowers Mix | Species Composition |
|---|---|---|
| Woodland edges | Country Lane<br> | Common Agrimony *(Agrimonia eupatoria)*<br>Cow Parsley *(Anthriscus sylvestris)*<br>Foxglove *(Digitalis purpurea)*<br>Hedge Bedstraw *(Galium mollugo)*<br>Hedge Garlic *(Alliaria petiolata)*<br>Lesser Knapweed *(Centaurea nigra)*<br>Meadowsweet *(Filipendula ulmaria)*<br>Nettle-Leaved Bellflower *(Campanula trachelium)*<br>Ox-Eye Daisy *(Leucanthemum vulgare)*<br>Red Campion *(Silene dioica)*<br>St. John's Wort *(Hypericum perforatum)*<br>Wood Avens *(Geum urbanum)* |
| Annual nurse crop | Cornfield Annuals<br> | Corncockle *(Agrostemma githago)*<br>Cornflower *(Centaurea cyanus)*<br>Corn Marigold *(Chrysanthemum segetum)*<br>Corn Poppy *(Papaver rhoeas)*<br>Corn Chamomile *(Anthemis arvensis)* |

*Annual - Lunt.*

*Biennial - Lunt.*

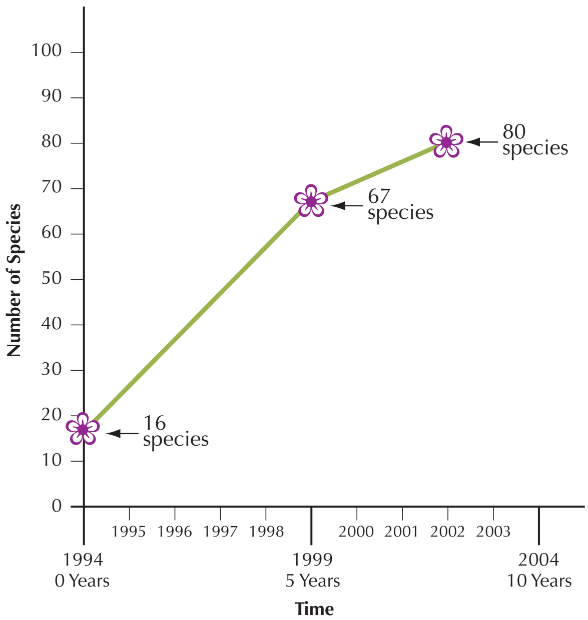
*Biennial and Perennial - Wheeldon Copse.*

*Perennial - Wheeldon Copse.*

Newly created areas may or may not develop into recognisable National Vegetation Survey Classifications, but will none-the-less form important future reserves for wildlife.

Bluebell *(Hyacinthoides non-scripta)*, has been successfully introduced to areas of new woodland planted on inverted land as sown seed and as bulbs introduced and covered during the ploughing process.

### Soil stripping site colonisation: Huyton, Merseyside.




## Woodland Wildflowers

By introducing woodland wildflower species at the inception of woodland plantings, it is possible to put in place a floristically rich seed bank. However, densely planted closed canopies will adversely affect this ground cover. In the light of the higher tree survival rates on soil inverted sites, consideration should be given to lower density planting in naturalistic drifts.

## Sand Dunes and Heathland

The inversion technique has been applied to extend sand dune systems in North Wales. Weed infested areas adjacent to existing dunes have been ploughed to expose sand for Marram Grass *(Ammophila arenaria)* to colonise. It is hoped that this will increase habitat areas for the Natterjack Toad *(Bufo calamita)* population found in this locality.

Likewise, in Shropshire and Cornwall soil inversion has been used to expose suitable substrates for heathland creation using heather litter. The Cornish project is part of the largest lowland heathland restoration project in Europe.

*Sand dunes at Talacre.*

# Fauna

## Farmland Birds

Surveys of the deep ploughed sites carried out between 2002 and 2007 identified significant positive impacts on the populations of farmland bird species. At Lunt on Merseyside the numbers of Skylark *(Alauda arvenis)* trebled in four years. Linnet *(Carduelis cannabina)*, Grey Partridge *(Perdix perdix)*, Song Thrush *(Turdus philomelos)*, Starling *(Sturnus vulgaris)* and Reed Bunting *(Emberiza schoeniclus)* also showed a steady increase in population numbers. Populations of these species on adjacent farmland and conventionally planted forestry are significantly lower. Casual recorders have reported Corncrake *(Crex crex)*, Bullfinch *(Pyrrhula pyrrhula)* and Hobby *(Falco subbuteo)* at this site.

| | 2003 | 2004 | 2005 | 2007 |
|---|---|---|---|---|
| Number of breeding pairs using inverted site | 7 | 14 | 22 | 52 |
| Number of breeding pairs using adjacent farmland and new forestry | 6 | 8 | 8 | 42 |
| Number of breeding species using inverted site | 5 | 8 | 10 | 26 |
| Number of breeding species using adjacent farmland and new forestry | 4 | 4 | 5 | 18 |

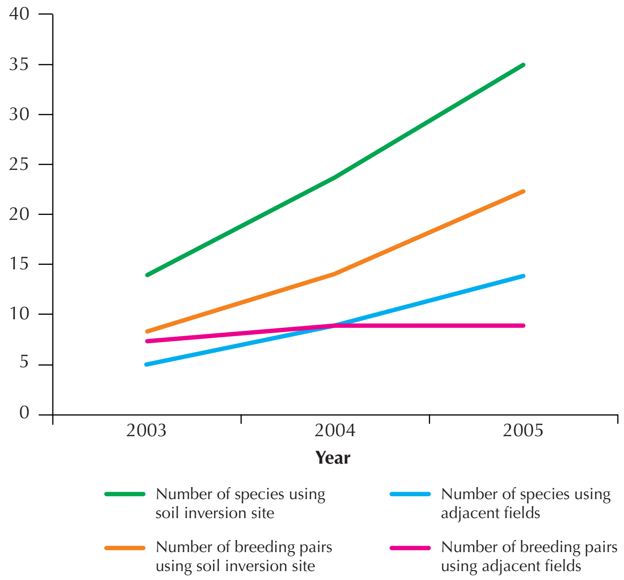
*Skylark (Alauda arvensis) nest.*

*A Lapwing (Vanellus vanellus) nest on an inverted site in Merseyside.*

**Table to show the number of breeding birds of Biodiversity Action Plan concern species, surveyed at Lunt, Merseyside.**

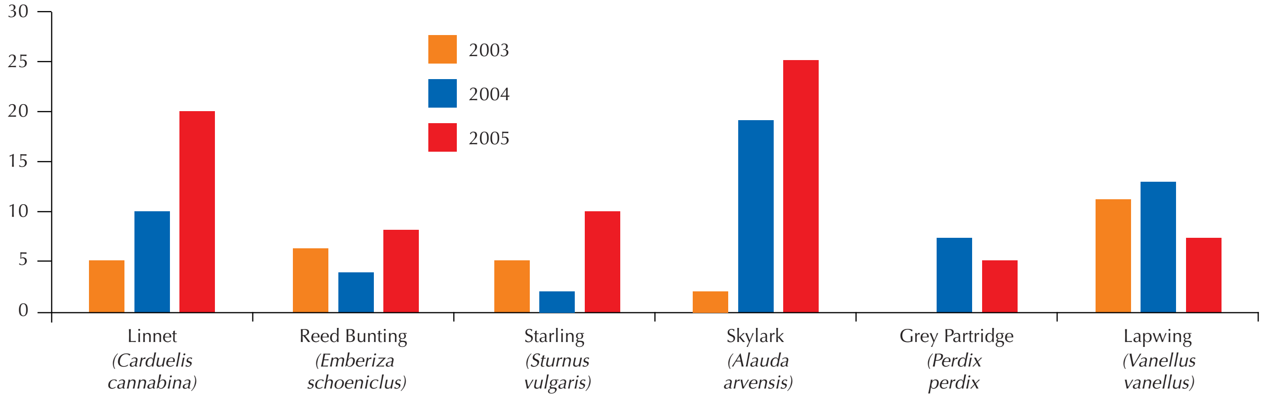
| Species | Number of breeding pairs 2005 | Number of breeding pairs 2007 |
|---|---|---|
| Grey Partridge *(Perdix perdix)* | 0 | 2 |
| Lapwing *(Vanellus vanellus)* | 1 | 3 |
| Skylark *(Alauda arvensis)* | 8 | 16 |
| Linnet *(Carduelis cannabina)* | 0 | 4 |
| Reed Bunting *(Emberiza schoeniclus)* | 3 | 3 |

**Comparative Bird Surveys, Lunt Merseyside 2003-2005**




Bird surveys from Lunt, Merseyside, recorded that between 2003 and 2007 the number of breeding bird species quadrupled, from 5 to 26. The number of breeding pairs has also increased sevenfold from 7 to 52 breeding pairs. The number of species recorded has increased by 45% to a total of 37. It has not been possible to make direct comparisons with any Farmland Bird Index, but clearly the increase in food source and habitat created are rapidly utilised by key species of Biodiversity Action Plan concern.

**Farmland Bird Numbers. Soil inversion Lunt, Merseyside.**




## Invertebrates

Evidence shows that deep ploughed sites sown with wildflowers provide very good habitats for numerous species of invertebrate.

The Wirral Wildlife recorder identified the key contributing factors for diverse invertebrate populations on a deep ploughed site in Cheshire as;

- *Profusion of flowers as nectar/pollen source (Butterflies, hoverflies, beetles, plant bugs, bees and wasps)*

*Flower beetles (Oedemera livida) in abundance at Wheeldon Copse.*

- *Range of structural spaces presented by the vegetation (spiders, harvestman and plant bug)*
- *Leaf/plant litter (spiders, springtails and beetles)*
- *Some bare ground (mining bees, digger wasps and spiders)*
- *Logs and stones placed on site (woodlice, slugs, beetles, snails)*
- *Woodland rides (hoverflies and butterflies)*
- *Proximity to farmyards (hoverfly and other fly species breeding ground)*

## Silver-Studded Blue *(Plebejus argus)*

Butterfly Conservation has used the topsoil inversion technique on the 30 hectare Prees Heath site in Shropshire, specifically to increase habitat for the nationally threatened Silver Studded Blue butterfly *(Plebejus argus)*. This fragment of heathland is the only remaining Midlands site for the species. The project inverted 30 hectares of ex-arable land with the objective of restoring it to a heathland habitat suitable for the butterfly's survival.

*Silver-studded Blue (Plebejus argus).*

## Marsh Fritillary *(Euphydryas aurinia)*

Landlife's success in establishing large areas of Devil's Bit Scabious *(Succisa pratensis)* on subsoils and inverted sites in the North West provides an opportunity for the conservation of the critically endangered Marsh Fritillary *(Euphydryas aurinia)*. The butterfly requires extensive stands of this plant as its larval food plant. At the edge of its range in Cumbria, such stands are rare and provide limited food sources to support costly re-introduction programmes, which are being undertaken.

*A large stand of Devils Bit Scabious (Succisa pratensis) established on inverted land.*

## Bumblebees *(Bombus sp.)*

Many once-common Bumblebees *(Bombus sp.)* and other Hymenoptera, are now becoming endangered. Soil inversion can be used to create large areas of nectar rich meadow to attract these invertebrates. A 2006 summer study of a 1 hectare patch of Vipers Bugloss *(Echium vulgare)* established on an inverted land, estimated that an average of 8 Bumblebees per $m^2$ were using the site as a food source on sunny days - that's 80,000 bumble bees!

## Mammals

During winter 2006-2007 an assessment of the Brown Hare *(Lepis capensis)* population at a deep ploughed site on Merseyside was undertaken. On every day of the study 2 to 3 adult Brown Hares *(Lepis capensis)* were recorded, while none were recorded in the surrounding farmland and traditionally planted forestry areas.

Casual observers have also recorded Brown Hare *(Lepis capensis)* leverets, Hedgehog *(Erinaceus europaeus)*, Stoat *(Mustela erminea)*, Weasel *(Mustela nivalis)*, Grey Squirrel *(Sciurus carolinensis)*, Mole *(Talpa europaea)* and Brown Rat *(Rattus norvegicus)*.

Woodland planting on this site was designed to provide habitat to encourage the spread of Red Squirrel *(Sciurus vulgaris)* from the isolated population found on the Sefton Coastline.

A one-off bat survey at a deep ploughed Cheshire site in its first year of development recorded 3 species: Common Pipistrelle *(Pipistrellus pipistrellus)*, Soprano Pipistrelle *(Pipistellus pygmaeus)* and Whiskered Bat *(Myotis mystacinus)*.

A small mammal survey carried out in 2007 revealed a healthy population at Lunt, Merseyside. Wood Mouse *(Apodemus sylvaticus)*, Common Shrew *(Sorex araneus)*, Pygmy Shrew *(Sorex minutus)* and Bank Vole *(Clethrionomys glareolus)* were all trapped in large numbers.

Land brought out of agricultural production and left fallow may have similar benefits in the short term, but it invariably reverts to stands of notifiable weed species such as Thistle *(Cirsium sp.)*, Ragwort *(Senecio jacobaea)* and, due to the high nutrient status, biodiversity interest declines over time.

*Hedgehogs (Erinaceus europaeus) populate a site 4 years after inversion.*

*Pygmy Shrew (Sorex minutes).*

# Community

Local communities should be informed about and involved in soil inversion projects. Circulating local residents and arranging wildflower sowing days at weekends gives people ownership and an interest in these evolving landscapes.

Sowing by hand can be done effectively and accurately over large areas. Areas of greater than a hectare have been sown with groups of between 6 and 20 people. Markers enable people to walk towards a target whilst broadcasting seed.

Bulk up seed to ensure there is sufficient to enable two passes at right angles to each other. These exercises have been enjoyable experiences and have created lasting friendships.

The resulting wildflowers have inspired people, who are keen to make contact. Simple signs that don't 'brand' the countryside give ramblers an opportunity to find out more, express their delight or simply comment. We have received poems, pictures, letters and YouTube™ postings in response to such signage.

*Community sowing event, Cornwall.*

*Broadcasting seed, Derbyshire.*

*Seed collecting for local distinctiveness, Merseyside.*

*Invitation and information signage, Derbyshire.*

# Management

## Herbicide regimes and cutting

The creation of new woodlands and meadows using soil inversion may lead to significant long-term reductions in maintenance requirements. The application of annual herbicide treatments around the base of each tree is not necessary as the grasses which compete for moisture are not present.

*Deep ploughing herbicide treated area to eradicate weed.*

The initial cost of ploughing and wildflower seeding is equal to five years herbicide treatment. Weed competition in a meadow situation is greatly reduced and management costs dealing with these problems are therefore also reduced. Wildflower areas will benefit from an annual cut in the late summer.

## Weed Infestations

An 8-hectare site in Alvanley, Cheshire had lain fallow for a year, resulting in total coverage with Creeping Thistle *(Cirsium arvense)*. The site was also surrounded on two sides by weed-infested fields.

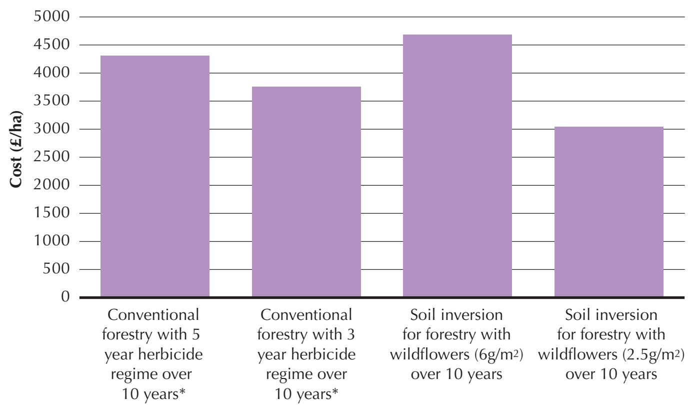
This light sandy site was sprayed with a translocating herbicide, and deep ploughed once the herbicide had been given sufficient time to take effect. It was a surprise to see thistle reappear across the whole site following the soil inversion. This was attributed to surviving root segments being brought up by the inversion process. A second treatment using a more targeted herbicide eliminated the problem. Creeping Thistle *(Cirsium arvense)* on site was subsequently limited to small numbers of seedlings arising from wind blown seed.

Further measures to control weed invasion involved sowing annuals and biennials in the wildflower seed mix to reduce spaces for weeds to germinate. A small number of Common Ragwort *(Serecio jacobaea)* plants occurred across the site and these were pulled by hand. This has produced a virtually weed free site of dense wildflowers and trees four years after sowing.

At Lunt, another large sandy site on Merseyside where no herbicide applications and no annuals were used, weed infestation was problematic. It was felt that a degree of wind and soil erosion resulted in the important dry layer being stripped off, exposing areas of weedy topsoil at the surface. Following strimming and spot spraying in years 2 and 3 the problem has been brought under control. It should be noted that even on this site even areas sown with grass suffered weed infestations.

Initial costs for inversion and high rate (i.e. $6g/m^2$) wildflower sowing are higher than that of conventional forestry. The reduced management costs over a 10 year period make the difference in costs minimal. The costs of inversion and sowing wildflower seed at a lower rate (i.e. $2.5g/m^2$) are cheaper than conventional techniques over a 10 year period.

**Graph to show the comparive costs of conventional forestry and forestry using the soil inversion technique.**




*Forestry Commission.

# Case Study - Wheeldon Copse

Wheeldon Copse at Alvanley, Cheshire, is former arable farmland owned by the Woodland Trust. It was in agricultural production until 2002. The 6.5 hectare site comprises a light sandy subsoil over laying New Red Sandstone base rock.

The aim of the joint project between the Woodland Trust and Landlife was to use the Forestry Commission's Jigsaw Challenge fund to assess the validity of the technique in creating a naturalistic amenity woodland as part of the Mersey Forest, accessible to the public and rich in wildlife.

*July 2003 before soil inversion.*

## Archaeology

An initial archaeological survey recorded evidence of light Prehistoric and Neolithic use of the site and worked flints were discovered in one area. Through discussions with the county archaeologist it was agreed to withdraw 1.1 hectares from the trial to safeguard artefacts.

## Work Programme

Following a fallow year, severe Creeping Thistle *(Cirsium arvense)* infestation was treated using a Glyphosate-based herbicide in July 2003.

The site was deep ploughed over a four-day period in August 2003 to depth of 900mm.

Creeping Thistle *(Cirsium arvense)* regenerated across the site and a second application of a combination herbicide was applied in September 2003, eradicating the problem.

In late September 2003 the site was drilled with a successional mixture of 29 annual and perennial wildflower seeds for a wide range of conditions at rates of 3g/m$^2$ and 0.75g/m$^2$ respectively. Local children aided in over-sowing the site.

## Seed mix

Red Campion *(Silene dioica)*
Foxglove *(Digitalis purpurea)*
Cow Parsley *(Anthriscus sylvestris)*
Bluebell *(Hyacinthoides non-scripta)*
Wood Avens *(Geum urbanum)*
Yellow Flag Iris *(Iris pseudacorus)*
Nettle Leaved Bellflower *(Campanula trachelium)*
Meadow Buttercup *(Ranunculus acris)*
Ox-eye Daisy *(Leucanthemum vulgare)*
Field Scabious *(Knautia arvensis)*
Meadowsweet *(Filipendula ulmaria)*
Teasel *(Dipsacus fullonum)*
Lady's Bedstraw *(Galium verum)*
White Campion *(Silene alba)*
Selfheal *(Prunella vulgaris)*
Yellow Rattle *(Rhinanthus minor)*
Cowslip *(Primula veris)*
Salad Burnet *(Sanguisorba minor)*
Weld *(Reseda luteola)*
Evening Primrose *(Oenothera fallax)*
Wild Carrot *(Daucus carota)*
Viper's Bugloss *(Echium vulgare)*
Lesser Knapweed *(Centaurea nigra)*

Kidney Vetch *(Anthyllis vulneraria)*
Cornflower *(Centaurea cyanus)*
Corncockle *(Agrostemma githago)*
Corn Marigold *(Chrysanthemum segetum)*
Corn Poppy *(Papaver rhoeas)*
Corn Chamomile *(Anthemis arvensis)*

Mixed native tree whips and shrubs were then introduced to the site in random patterns mimicking natural downwind colonisation of the site.

*Professor Tony Bradshaw FRS, Wheeldon Copse July 2007.*

## Tree species

English Oak *(Quercus robur)*
Sessile Oak *(Quercus petrea)*
Silver Birch *(Betula pendula)*
Holly *(Ilex aquifolium)*
Common Hawthorn *(Crataegus monogyna)*
Crab Apple *(Malus sylvestris)*
Rowan *(Sorbus aucuparia)*
Field Maple *(Acer campestre)*
Hazel *(Corylus avellana)*
Common Elder *(Sambucus nigra)*

*August 2003.*

*September 2003.*

*July 2004.*

*June 2005.*

*June 2006.*

*June 2007.*

## Outcome

Successful autumn establishment of annuals, particularly Corn Chamomile *(Anthemis arvensis)* and Cornflower *(Centaurea cyanus)* safeguarded this sloping site from soil erosion and provided a nurse crop for the successful establishment of biennials, perennials and tree whips the following year. The spectacular flower display created considerable community interest. Introductions of locally-sourced cuttings of Greater Stitchwort *(Stellaria holostea)* and Ground Ivy *(Glechoma hederacea)* from the adjoining woods, contributed to maintaining local distinctiveness. These were planted by local school children.

In subsequent years the site has evolved from predominantly biennials such as Wild Carrot *(Daucus carota)* and Foxglove *(Digitalis purpurea)*, through extensive swathes of Red Campion *(Silene dioica)*, Meadow Buttercup *(Ranunculus acris)* and Ox-Eye Daisy *(Leucanthemum vulgare)* to longer-lived perennials such as Lesser Knapweed *(Centaurea nigra)* and Field Scabious *(Knautia arvensis)*.

A vegetation survey carried out in August 2006 recorded 83 plant species and 20 grasses. 28 of the 29 sown species were present with the exception of Bluebell *(Hyacinthoides non-scripta)*, which can take up to 7 years to flower from seed. Tree growth was exceptional and the summer drought of 2006 had had little or no impact on their survival.

Andrew Sharkey, the Woodland Trust (Head of Woodland Management), invited Woodland Trust Officers attending a training visit to Wheeldon to first look up the vista of flowers and trees, and then close their eyes and envisage a standard planting scheme- there are alternative ways of doing things.

*Oak (Quercus robur) at Wheeldon Copse, June 2004.*

*Trees at Wheeldon Copse, July 2007.*

# National Trial Sites

A sample of national soil inversion sites carried out by Landlife at various stages of development.

*Glacial Sands, Lunt, Merseyside (Forest Enterprise).*

*Clay, St Austell, Cornwall (Eden Project).*

*Sandy Clay, Coton Wood, Derbyshire (Woodland Trust).*

*Light Clay, Penguin Wood, Derbyshire (Woodland Trust).*

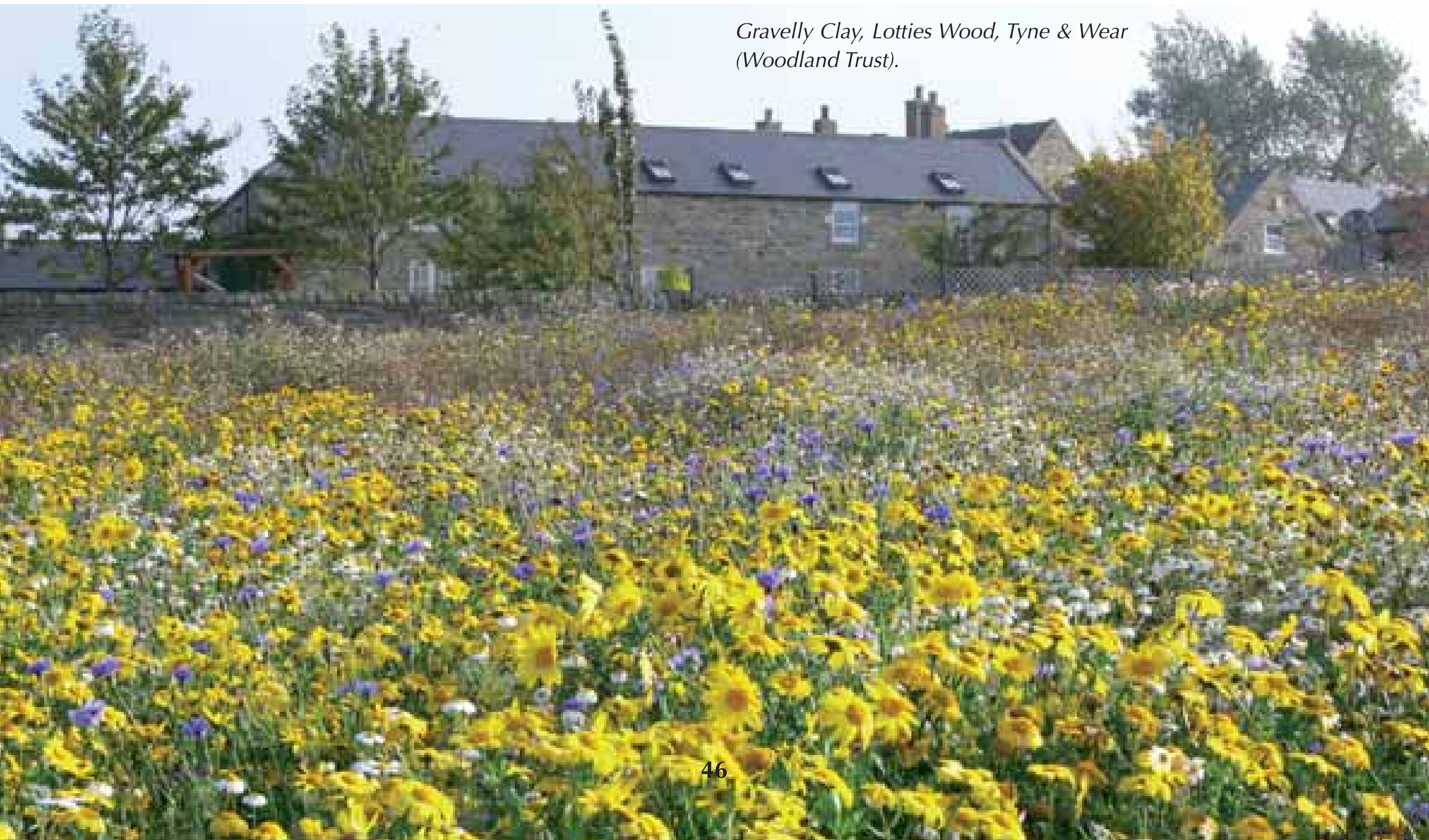
*New Red Sandstone, Wheeldon Copse, Cheshire. (Woodland Trust).*

*Heavy Silt, Paddington Meadow, Cheshire (Halton MBC).*

*Granite Type, Billa Barra Hill, Leicestershire (National Forest).*

*Sand, Chadkirk Country Park, Cheshire (Stockport MBC).*

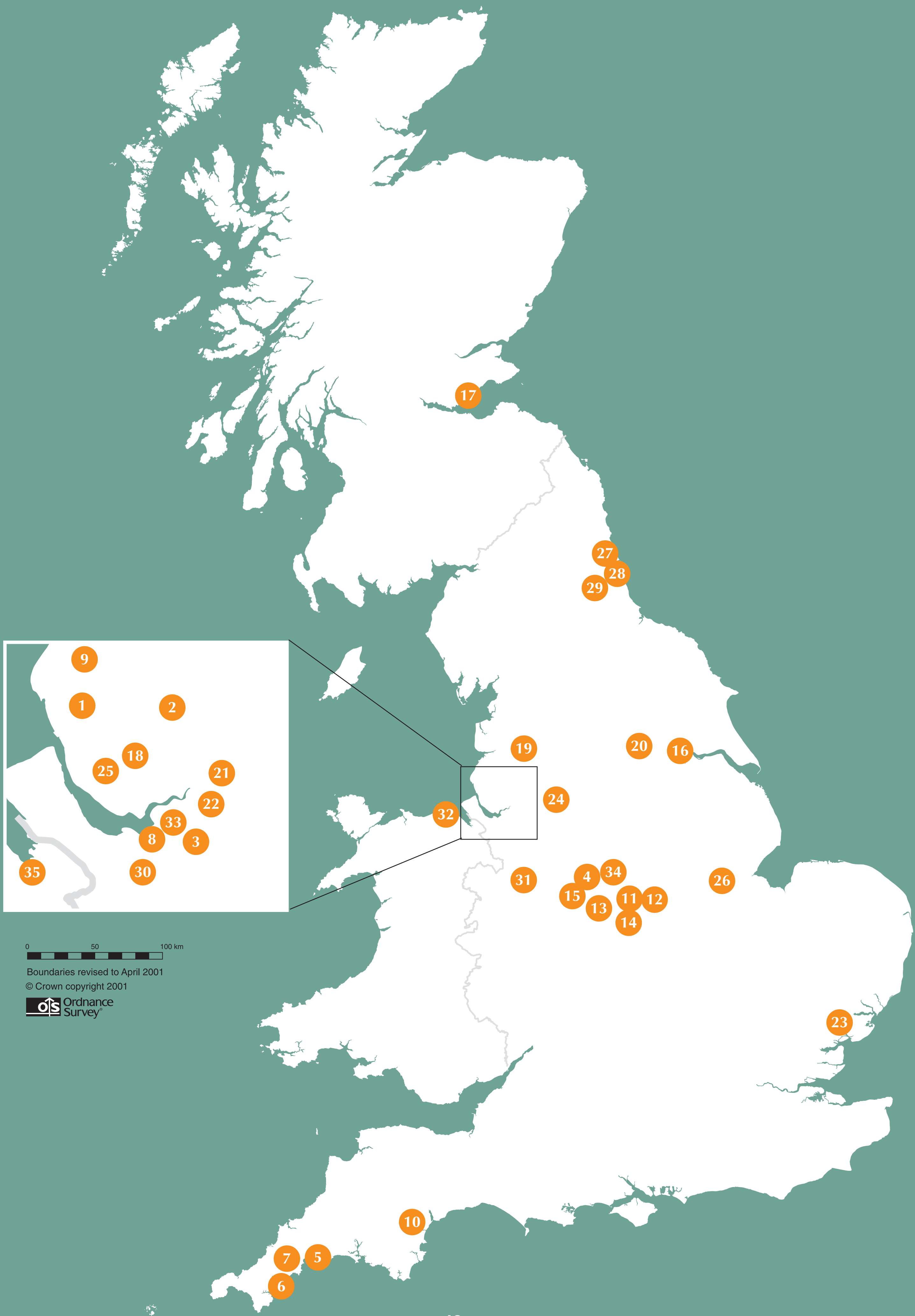
*Sand, Runcorn, Cheshire (Halton MBC).*



*Gravelly Clay, Lotties Wood, Tyne & Wear (Woodland Trust).*

# Map of UK Sites

| | Name | Town | County | Organisation | Size (ha) |
|---|---|---|---|---|---|
| 1 | Rose Farm | Lunt | Merseyside | Forest Enterprise/ Mersey Forest | 10 |
| 2 | Lily Farm | Wigan | Greater Manchester | Forest Enterprise | 1 |
| 3 | Old Pale Farm | Delamere Forest | Cheshire | Forest Enterprise | 1.5 |
| 4 | Billa Barra Hill | Bardon | Leicestershire | National Forest | 2 |
| 5 | Eden Project | St. Austell | Corwall | Eden Project | 1.5 |
| 6 | Pines Tip | Melbur | Cornwall | English Nature | 5 |
| 7 | Carloggas Down | Penthwick | Cornwall | English Nature | 0.5 |
| 8 | Wheeldon Copse | Alvanley | Cheshire | Woodland Trust | 7 |
| 9 | Baxters Farm | Southport | Merseyside | Baxters | 2 |
| 10 | Venn Ottery | Exmouth | Devon | Devon Wildlife Trust | 1 |
| 11 | Burroughs Wood | Ratby | Leicestershire | Woodland Trust | 1 |
| 12 | Pear Tree Wood | Ratby | Leicestershire | Woodland Trust | 1 |
| 13 | Foxley Wood | Linton | Derbyshire | Woodland Trust | 1 |
| 14 | Centenary and Royal Tigers Wood | Bagworth | Leicestershire | Woodland Trust | 1 |
| 15 | Coton Wood | Coton in the Elms | Derbyshire | Woodland Trust | 1 |
| 16 | Cowick Hall | Snaith | Yorkshire | Woodland Trust/ Croda International | 5 |
| 17 | Geordie's Wood | Muckhart | Clackmannanshire | Woodland Trust | 12 |
| 18 | St. Benedict's Wood | Rainhill | Merseyside | Woodland Trust | 1 |
| 19 | Polyphemus Wood | Darwen | Lancashire | Woodland Trust | 1 |
| 20 | Ruddings Farm | Wetherby | Yorkshire | Till Hill Associates | 20 |
| 21 | Paddington Meadow | Warrington | Cheshire | Warrington MBC | 2.5 |
| 22 | Moore Nature Reserve | Runcorn | Cheshire | Halton MBC | 2 |
| 23 | Fordham | Colchester | Essex | Forest Research | 0.5 |
| 24 | Chadkirk Country Park | Stockport | Greater Manchester | Stockport MBC | 2 |
| 25 | New Pale Farm | Huyton | Merseyside | Woodland Trust/ Mersey Forest | 1 |
| 26 | Londonthorpe Wood | Grantham | Lincolnshire | Woodland Trust | 3 |
| 27 | Hedley Hall | Sunniside | Tyne and Wear | Woodland Trust | 1 |
| 28 | Lotties Wood | Sunniside | Tyne and Wear | Woodland Trust | 1 |
| 29 | St. Bedes and Bright Lea Wood | Ouston | Tyne and Wear | Woodland Trust | 1 |
| 30 | Thorn Wood | Hartford | Cheshire | Woodland Trust | 1 |
| 31 | Prees Heath | Whitchurch | Shropshire | Butterfly Conservation | 30 |
| 32 | Sand Dunes | Talacre | Flintshire | Countryside Council for Wales | 1 |
| 33 | Dutton Park Farm | Dutton | Cheshire | Woodland Trust | 5 |
| 34 | Penguin Wood | Botany Bay | Leicestershire | Woodland Trust | 10 |
| 35 | Broughton | Connah's Quay | Flintshire | North East Wales Wildlife Trust | 4 |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Boundaries revised to April 2001
© Crown copyright 2001
Ordnance Survey

# Before and After


*Londonthorpe Wood, Grantham, Lincolnshire (Woodland Trust). 3ha woodland glade and meadow creation on heavy loams.*


*Foxley Wood, Linton, Derbyshire (Woodland Trust). 1ha new woodland glade creation on heavy clay.*


*Rose Farm, Lunt, Merseyside (Forest Enterprise/Mersey Forest). 10ha new woodland creation for Red Squirrel (Sciurus vulgaris) habitat on sand and clay.*

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**Glen, E., E.A.C. Price, S.J.M. Caporn, J Carroll, M.L.M. Jones & R. Scott (2007).** A novel technique for restoring species-rich grassland. In J.J. Hopkins (Ed.) *High Value Grassland: Providing Biodiversity, a Clean Environment and Premium Products.* British Grassland Society Occasional Symposium No. 38, pp 221-224.

**Glen, E. (1997).** A novel technique for addressing ecological restoration constraints on ex-arable land. Presentation given at 2007 Society for Ecological Restoration Summer School, Radboud University, Nijmegen, the Netherlands. URL: **https://www.ser.org/europe/Nijmegen.asp**

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*Suppliers of native British wildflower seeds and plants.*

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